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ACTA RADIOLOGICA
EDITA IUSSU SOCIETATUM RADIOLOGICARUM
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VOL. 43 FEBRUARY 1955 FASC. 2

TRIUROL IN CEREBRAL ANGIOGRAPHY

by

Sven Odén

The ideal contrast medium for cerebral angiography should meet the following requirements: its use should not entail any risk of complications at the time of the examination nor any discomfort to the patient, it should not cause late damage, and it should be rapidly and easily eliminated from the organism. Among all the contrast media so far used in cerebral angiography, none has met all these demands. The Swedish preparation Umbradil has, according to our clinical experiences as well as the experimental investigations of BROMAN and OLSSON, proved most satisfactory. In recent years, a new contrast medium, sold in the United States under the trade name of Urokon, has become available. Favourable experiences in renal examinations obviously suggested its trial in cerebral angiography. In 1952, SEAMAN and SCHWARZ reported experiences gained with Urokon-sodium 30 % (buffered to a pH of 7); 40 angiographies were performed on 36 patients, slightly more than 9 ml, on an average, being injected per examination. Their impression was that the immediate reaction to the injection was definitely less than that usually observed with other contrast media. The flushing of the skin and the temporary dilatation of the pupil which, according to the authors, invariably accompany cerebral angiography executed with other contrast media were not observed when Urokon was used, although with the latter the patient experienced a burning sensation during the injection. In 2 cases, mild neurologic signs — transient facial paresis and mild hemiparesis — were observed. In 2 other cases, symptoms and signs previously present were accentuated. In both of the latter two cases, hypertension and arteriosclerosis were presented, factors which, according to the authors, probably increase the hazards of arteriography.

GASS and JACOBSON, the following year, in a preliminary report gave

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From the Roentgen Department (Director: Professor ERIK LINDGREN) of Serafimerlasarettet, Stockholm, Sweden.

an account of the results of 62 arteriographies on 52 patients, ranging from 10 to 68 years of age. As a rule, 10 ml were injected per injection, and up to a total of 60 ml during the same examination. Summarizing their experience, the authors state that Urokonsodium 30 % may be used as a contrast medium in cerebral angiography with no greater risk or discomfort than with Diodrast 35 % and the resulting arteriograms are of comparable quality. The authors, in an appendix, report that they have later made a total of 200 arteriograms without any permanent neurologic effect. Most of these were obtained with only 5 ml of contrast medium per injection. In 2 cases, the contrast medium was diluted to 20 % and in one case to 10 %, but the resulting arteriograms were too faint to qualify as adequate cerebral arteriograms.

The same year, LIN, MURTAGH, WYCIL and SCOTT published similar investigations from 100 angiographies. They used 8 to 10 ml of medium per injection. In only one case was there a complication in the form of transient unconsciousness in connection with the injection. In all other cases, no complications, including any skin reactions, were observed. The authors consequently hold that they have obtained considerably less complications with Urokon than with Diodrast 35 %. The discomfort experienced by the patient was also considerably less. As an indication of this, the authors cited that general anesthesia was generally necessary for satisfactory sequence angiograms when Diodrast 35 % was used, while with Urokon, 50 % of the examinations could be conducted under local anesthesia. The authors point out, however, that the difference between complications with Diodrast and Urokon may be due to their having used considerably larger doses in their examinations with the former. SCOTT, SIMRIL and SEAMAN, in a paper on intracerebral arteriovenous malformations, published in 1954, stated that they have used 7 to 10 ml Urokonsodium with satisfactory results.

Judging from these American experiences, it would seem that the new contrast medium Urokon causes fewer complications and less discomfort to the patient than contrast media of the Diodrast type. In the American investigations, the comparison has been with Diodrast. According to our clinical experience as well as the experimental investigations by BROMAN and OLSSON, this latter contrast medium is, however, considerably more irritating than the Swedish preparation Umbradil, despite the fact that both solutions are described as having the same chemical structure, diethanolamine salt of 3.5 diiodo-4 pyridone-N-acetic acid. The statement by SEAMAN and SCHWARZ that dilatation of the pupil always accompanies cerebral angiography, is not in accordance with our experience with Umbradil. When Diodrast is employed, it seems that in the majority of cases the cerebral angiographic examination must be conducted under general anesthesia, which is required only exceptionally

with Umbradil. For these reasons it seemed desirable to make a comparison between Umbradil and Urokon.

Urokon consists of sodium 3-acetylamino-2,4,6-triiodo benzoate. This substance is now also manufactured in Sweden. We have used the preparation manufactured by the firm Leo and sold under the trade name of Triurol. The molecular weight of the diethanolamine salt is 510 and that of the new contrast medium 579. Spot tests have indicated its pH to be between 6.64 and 6.7. Triurol, in a solution of the same concentration as Umbradil, contains approximately 32 % more iodine. In other words, in iodine content, 20 ml of Umbradil 35 % corresponds to just over 15 ml of Triurol 35 %. In solutions of the same concentration, Triurol is somewhat less hypertonic (13 %), but the difference becomes considerable if the same amount of iodine is introduced in the same volume. The reasons for the complications and discomfort which these contrast media may cause in cerebral angiography are probably complicated, but osmotic conditions definitely have a certain influence, as do the amount of contrast medium and the length of time that the wall of the vessel is affected. If a solution of sodium chloride with the same osmotic pressure as the contrast medium is injected, in cerebral angiography, the patient suffers the same discomfort in the form of a burning sensation. Flushing of the skin and pupil reaction may also be observed, and in one case we have even observed a mild and rapidly transient paresis of an arm and leg after a single injection of 7 ml of a 4 % solution of sodium chloride. From the point of view of iodine, a 35 % solution of Umbradil corresponds to a 26.5 % solution of Triurol. The latter has an osmotic pressure which is considerably less (not quite 62 %) than a 35 % solution of Umbradil. By employing Triurol, it is thus possible to obtain a solution with the same iodine content as Umbradil 35 % but with a considerably lower osmotic pressure. Since Umbradil 35 % yields completely satisfactory image quality in cerebral angiography, provided the correct technique is used and the injection made through the internal carotid artery, a 25 % solution of Triurol should give approximately the same result but with less discomfort to the patient.

In order to obtain an idea as to whether the discomfort caused to the patient when Triurol is employed in practical work is so much less than with Umbradil, we carried out double examinations in 102 cases. The examinations were, as a rule, made in such a manner that one contrast medium was injected into the internal or common carotid artery of one side, and the other into the corresponding vessel of the other side. In a few cases, however, both contrast media were injected on the same side. Only such patients were included in this series as were considered capable of observing and giving a clear account of their sensations during the contrast injection. The patients had no knowledge of which contrast

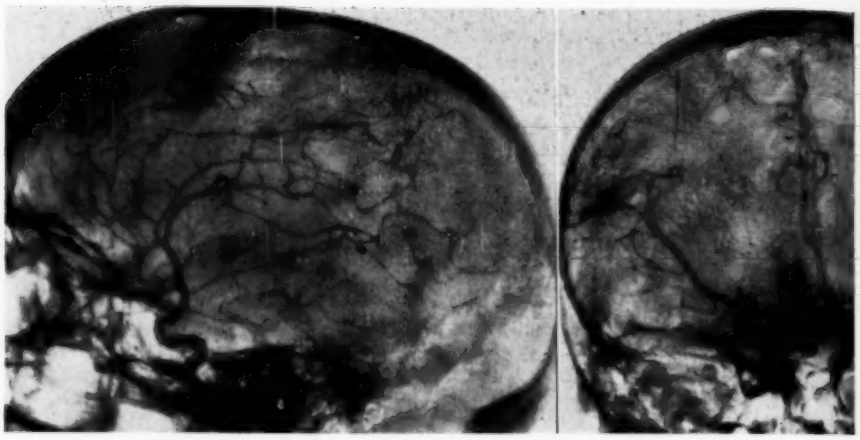

Fig. 1. Angiogram obtained with 7 ml Triurol 25 % in a case of tumour in the temporal lobe.

medium was being used. Triurol was used in different concentrations, 25, 30 and 35 %, and was compared with Umbradil 35 and 42.5 %. Out of 50 patients, in whom Triurol 25 % was compared with Umbradil 35 %, 26 considered that Triurol caused considerably less discomfort than Umbradil. Twenty-one stated that the difference was not sufficiently marked for them to have any preference. Three considered the two preparations were in every way identical. When, however, Triurol 30 % was used, only 2 out of 19 patients considered that Umbradil definitely produced more discomfort. When Triurol 35 % was employed, most patients considered that Triurol caused greater discomfort than Umbradil. In all these examinations 7 ml were injected per injection, and the number of injections per examination was never less than 3 and never higher than 6. In a relatively few cases, Triurol was compared with Umbradil 42.5 %. Umbradil then always caused greater discomfort than Triurol, even in a 35 % solution. The practical tests thus perhaps did not give quite as satisfying results as theoretic considerations may have led one to expect. Even so, more than half the patients considered that the discomfort was considerably less with Triurol 25 % than with Umbradil 35 %. The contrast density obtained with Triurol 25 % was quite satisfactory (Fig. 1).

This material is, however, almost completely lacking in the objective changes that contrast injections may cause. Thus, flushing of the skin was seen only once, and no other complications were observed. According to SEAMAN and SCHWARZ, flushing of the skin could always be observed when contrast media other than Urokon were used. From our experience

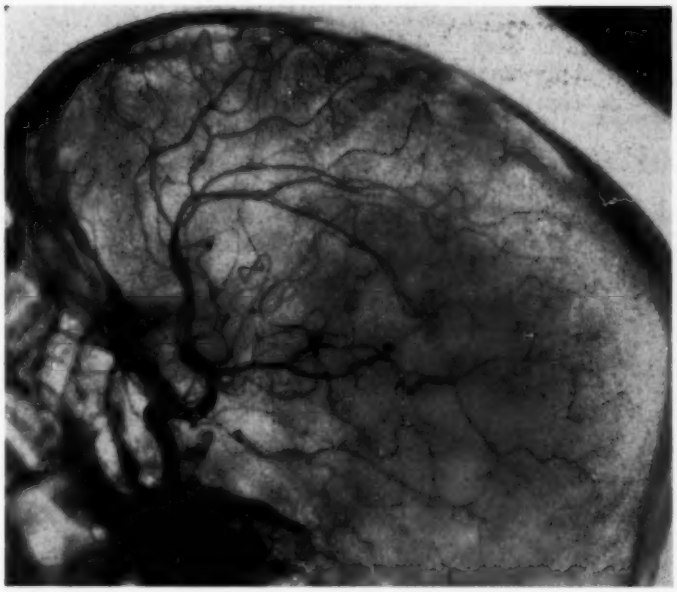

Fig. 2. Rapid serial angiography. 6 films/sec. 3 ml Triurol 50 %.

with Umbradil, this is far from true, but, up to now we have observed that the reaction occurs much more frequently than when Triurol is used. None of the reactions our patients have experienced have been so severe that more than local anesthesia has had to be used.

Following the comparative experimental series described above, we have changed over to the routine use of Triurol, and have examined an additional 142 cases, among them 37 tumours and 10 arteriovenous malformations or arterial aneurysms, and 3 subdural hematomata. In this series, one patient suffered rapidly transient general urticaria just after the conclusion of the examination, indicating hypersensitivity to the contrast medium. We shall therefore in future carry out sensitivity tests with 2 ml of Triurol injected intravenously the day before the examination, as was our practice with Umbradil. No other complications have been observed. The employment of Umbradil in cases of recent head injury has always meant a risk of a possible serious deterioration in the condition of the patient in connection with the contrast medium examination. Certain caution has therefore been necessary with this type of examination. The three cases of subdural hematoma examined with Triurol were all recent head injuries (the general condition of one case was poor)

and were not unfavourably affected by the examination. These cases are few in number, but may still be considered perhaps the best indication that the new contrast medium, at least in the form of Triurol, is less irritating than contrast media containing the diethanolamine salt, as in Umbradil.

In rapid serial angiography, a small amount of contrast medium of relatively great density is desirable. By reason of the rapid sequence of films, the passage of the agent through the vessels may be followed. If more contrast medium is injected, a larger portion of the vascular system becomes contrast filled — in certain phases, arteries and veins simultaneously — and this may make the interpretation of the films difficult. We have found that an injection of 3 or 4 ml of Triurol 35 or 50 % in such examinations produces excellent results without any serious discomfort to the patient: in certain cases, no sensation at all has been experienced with Triurol 50 % used in small quantities (3 ml). These experiences confirm that the osmotic pressure of the contrast medium is by no means the only important factor in creating discomfort to the patient, but that the amount injected also plays an important part.

SUMMARY

The contrast media employed in cerebral angiography are discussed and the differences between the newer agent Triurol (Urokon) and Umbradil (Diodrast) pointed out. From 102 double examinations performed, it appeared that the former substance causes much less discomfort to the patient. The author's experiences of Triurol in a further 142 cases are also recorded. The general conclusion is reached that the employment of this contrast medium in angiography is to be preferred.

ZUSAMMENFASSUNG

Die bei der cerebralen Angiographie benutzten Kontrastmittel werden besprochen und die Unterschiede zwischen dem neuen Mittel Triurol (Urokon) und Umbradil (Diodrast) werden hervorgehoben. Aus 102 mit beiden Kontrastmitteln durchgeführten Untersuchungen geht hervor, dass die erstere Substanz dem Patienten weniger Unbehagen verursacht. Die Erfahrungen des Verfassers mit Triurol in weiteren 142 Fällen werden ebenfalls berichtet. Es wird die Schlussfolgerung gezogen, dass die Benutzung dieses Kontrastmittels für die Angiographie zu bevorzugen ist.

RÉSUMÉ

L'auteur étudie les produits de contraste utilisés en angiographie cérébrale et souligne les différences entre le récent produit, le Triurol (Urokon) et l'Umbradil (Diodrast). De 102 doubles examens, il ressort que le premier produit est beaucoup moins pénible pour le malade. L'auteur rapporte aussi ses observations sur 142 autres cas où il a employé le Triurol. Il arrive à cette conclusion générale, que l'emploi de ce produit de contraste est préférable en angiographie.

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FROM THE FIRST SURGICAL UNIVERSITY CLINIC (DIRECTOR: PROFESSOR P. E. A. NYLANDER) AND ITS ROENTGEN DEPARTMENT (DIRECTOR: HEINO LAITINEN), HELSINKI, FINLAND

THE PNEUMOMEDIASTINUM

by

Juha Tapiovaara

The results obtained in the field of thoracic surgery in recent years have made it necessary for roentgenologists to develop new methods of examination, especially of the mediastinum and adjacent regions. The various parts of the mediastinum produce similar homogeneous soft tissue shadows and their differentiation even by tomography is not possible. Efforts have been made to find a contrast medium which might be introduced between the mediastinal organs and delineate them in the roentgenogram. This object has been attained in recent years by the use of pneumomediastinography. Since 1952 we have used this new and still rather experimental method; it has already given promising results which may deserve to be more widely known.

Method of Examination

As the use of hypertonic contrast media is injurious to the pleura and the mediastinum, gas has been used for mediastinal contrast purposes. The pneumomediastinum methods based on the use of gas which are in use at the present time may be divided into two groups according to whether the direct or indirect routes are employed.

1) *Direct routes*, in which the purpose is to introduce the gas into the immediate vicinity of the area under examination. This method of examination was originally developed by CONDORELLI, who as a result of experiments carried out since 1934 suggested a puncture superior to the manubrium sterni for the injection of gas into the anterior superior mediastinum for the radiologic examination of this region.

Examination of the posterior mediastinum was also based on the experiments carried out at the same time by CONDORELLI. The uncertain antero-tracheal route which he employed at first was later replaced by

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transtracheal insufflation, in which the puncture needle is introduced through the trachea into the loose connective tissue between the trachea and the oesophagus. CONDORELLI published this method in 1949. In 1941 CIARLA had described the peridural route for examination of the posterior mediastinum, the site of puncture being between Th. IX and X.

2) *Indirect routes.* Condorelli's method has not gained very wide use for it involves manipulation in areas which may cause discomfort to the patient and difficulties to the examiner. Furthermore, it permits the examination of only the anterior or the posterior mediastinum at a time, depending on the site of injection. Although RUIZ RIVAS in 1948 in his pioneer work on subserous emphysema expressed a hardly encouraging opinion on the use of emphysema in the mediastinal region, and although some investigators actually feared the rise of gas outside the mediastinal cavity and sought to prevent it, MACARINI and OLIVA (1952), who had greatly promoted the use of gas insufflation, and BACCAGLINI (1951) proposed the adoption of the method presented by DE GENNES, MAY and SIMON (1950). In the latter method, which is based on the principles of Ruiz Rivas, the gas is introduced by praecoccygeal injection and moves from the retroperitoneal space into the anterior and posterior mediastina simultaneously.

Writer's Observations

When in the summer of 1952 the gas insufflation method was brought into use in our clinic, the intention was primarily to obtain a more thorough and accurate method of roentgenologic diagnosis of processes in the region of the mediastinum. For this purpose we chose the praesacral gas insufflation method of Ruiz Rivas, combined with tomography.

This method has been used in 30 patients from 20 to 61 years of age, 4 of whom were female, all being admitted to the Department for Thoracic Surgery. Ordinary radiography and tomography having failed to determine with certainty the relation of the process under investigation to the mediastinum and its structures, a combination of oxygen insufflation and tomography in sagittal and lateral projections was employed.

For the insufflation the patient is placed on the table with the pelvic region elevated as for a retropneumoperitoneal examination. Following anaesthetisation with 2 % xylocainexadrin, a long injection needle is introduced at the level of the sacrococcygeal articulation 2 to 3 finger-breadths to the left or right of the median line and is brought under the lateral margin of the sacrum and, following the surface of the bone, to its ventral surface in the median line. Aspiration with a Record syringe and insufflation of a few millilitres of air will indicate the best position of the needle in relation to blood vessels and tissues. An air pump attached to

an oxygen bomb is connected to the needle and the insufflation of oxygen is started at a fairly slow rate, 15 minutes being taken for the injection of about 1,500 ml at a pressure of 20 to 22 cm of water. The gas will then have time to spread evenly from the pararectal tissue into the retroperitoneal space without untoward pain to the patient. The use at first of 2,000 ml of gas gave a definitely poorer result than the smaller amounts now used. BACCAGLINI assumes that in such cases the gas collects in the central portions of the retroperitoneal space. After completion of the insufflation the patient is placed in the prone position for 20 to 30 minutes with the upper part of the body slightly elevated to permit the gas to mount higher. Various sitting postures are also recommended, and large excursions of the diaphragm also appear to facilitate movement of the gas into the mediastinum. It is as well to examine its progress by fluoroscopy. The tomographic examination is usually started 1 to 1½ hours after the commencement of the gas insufflation.

The method is based on the continuity which exists between the pelvic, retroperitoneal and mediastinal connective tissues. Gas injected into the pararectal tissue is diffused into the pelvic connective tissue, some portion continuing into the retroperitoneal region, where, after filling, for instance, the perirenal spaces, it finally reaches the level of the caudal surface of the posterior portions of the diaphragm. The large connective tissue areas which so far have facilitated the rapid progress of the gas end here and the rate of advance is distinctly retarded as the gas moves in a cranial direction and into the mediastinum. At this stage it penetrates chiefly through the apertures between the crura of the lumbar portion of the diaphragm and through the oesophageal foramen and the aortic hiatus with which these are connected. The communication along the connective tissue in these openings is narrow and retards the progress of the gas, but is sufficiently large to permit it to rise according to physical laws from the retroperitoneal space into the mediastinum and the sub-pleural space.

In the posterior mediastinum the gas moves along the spaces dorsal to the descending aorta and the oesophagus. The space bounded by the diaphragm and posterior portion of the pericardium becomes filled with gas and in the roentgenogram these organs are visualised with sharp margins. Gas is also evident in the region of the arch of the aorta and the hili of the lungs, and the large blood vessels as well as the trachea and the large bronchi may be seen surrounded by narrow bands of gas.

From his investigations CONDORELLI drew the conclusion that there is no connection between the posterior and anterior mediastina because of the intervening fibrous membrane which probably is situated at the level of the intrathoracic prolongation of the deep fascia of the middle cervical aponeurosis. However, LENTINI and BARBIERI (1950) observed

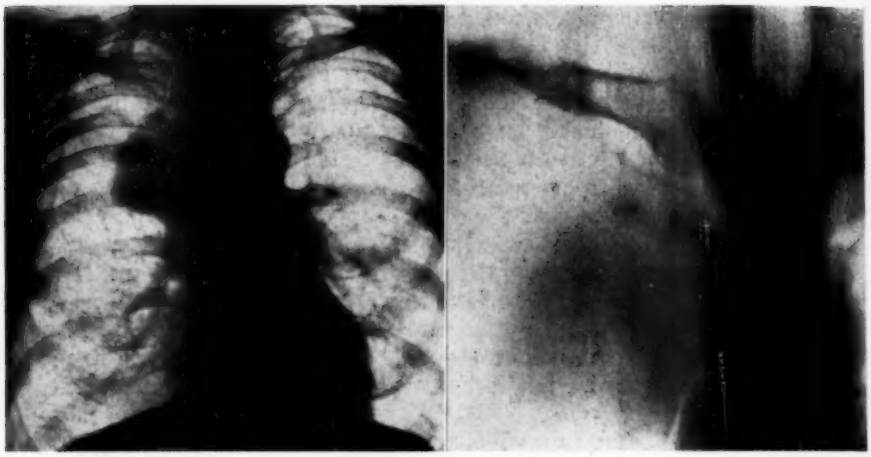
that a small amount of gas, insufflated into the anterior mediastinum, penetrated also into the posterior mediastinum in the region of the brachiocephalic trunk. More recently CONDORELLI, TURCHETTI and PIDONE (1951) have also noted that following the insufflation of gas into the posterior mediastinum a small amount passes into the anterior mediastinum. As a result of praesacral insufflation, gas appears in the anterior mediastinum, particularly in the area bounded by the ventral part of the pericardium and the diaphragm, and more cranially in the spaces posterior to the sternum. It seems apparent that the penetration of the gas into these areas from the posterior mediastinum occurs through the fibrous layer between the pericardium and the diaphragm and through the aortic opening situated more cranially in the cervical fascia. It also seems probable that from the abdominal region the gas is able to move directly into the anterior mediastinum through the sternal attachments of the diaphragm.

In general, the gas, propelled by the intrathoracic pressure and its own low pressure, moves slowly in the region of the mediastinum and its progress is dependent on the looseness of the tissues. Thus 1 to $1^1/_2$ hours after the insufflation was completed there was emphysema in the neck; crepitation was observed as early as 10 minutes following the injection in two cases only.

In all the cases the patients endured the procedure well. A sensation of pressure and some pain in the upper abdominal region was more pronounced in only two cases, but in these the distress subsided fairly quickly when the gas entered the thorax. Dysphonia was present in one case. After their return to the ward following the examination, no particular features were noted in the patients, but they were nevertheless kept confined to bed throughout the day of the examination.

The following are three typical cases:

Case 1. A farmer, aged 61, whose history revealed no unusual features and who had generally been well, and had, since August, 1952, sharp pain in the right side of the chest, occasionally associated with cough. Recently the sputum was sometimes stained pink. Since the beginning of October, 1952, he had been incapable of work. For many years he had smoked twenty cigarettes daily. Because of the pain he consulted a physician, who referred the patient to our clinic with the diagnosis of a mediastinal tumour. On admission on 29 October 1952, he was in a satisfactory physical condition, although lean. The thorax was symmetric. Respiratory movements were small and there was lagging on the right side. The respiratory sound was weak over a palm-sized area in the dorsal upper field of the right lung. No râles or friction sounds were heard. Dextral to the sternum, at about the level of Th. II—III, there was relative dullness over an area about the width of two fingers; other areas were hypersonorous. Laboratory test results were Hb 79, E 4.4 mill., I 0.90, L 10,050, SR 54, WR —, Kahn —, Chol. —, tb. culture from sputum —, tumour cells in sputum —. Thorax roentgenography and tomography revealed a dense, apple-sized shadow which was connected by a wide pedicle to the right side of the mediastinum superior to the hilus. As it was not possible to determine whether this was a



a. b.

Fig. 1. Case 1. a. Tumour adjoining the mediastinum above the right hilus. b. Pneumomediastinogram. Gas between tumour and mediastinum. Finger-breadth connection with mediastinum.

pulmonary or mediastinal tumour, pneumomediastinography was performed. The gas was seen to penetrate medially to the shadow, but in all levels the finger-sized pedicle was seen, continuing into the mediastinum. *Pneumectomia palliativa l. dx.* was performed on 7 November (Prof. NYLANDER). In the anterior segment of the upper lobe there was a tumour about the size of a tennis ball, attached to the ribs and the sternum and by a pedicle the thickness of a finger to the mediastinum. Histologic examination: *Carcinoma spinocellulare.* Recovery was uneventful and was followed by roentgen therapy (Figs. 1 a and b).

Case 2. A farmer, aged 54, had earlier been in good health. Fluorography performed in June 1953, showed a tumour-like, round shadow in the right cardiophrenic angle. The patient had never been a smoker. No cough was present but he had lost some weight. When admitted to the clinic on 28 September 1953 he was in good physical condition. Except for some hard, pea-sized glands in both axillary regions, no abnormal findings were made. In the roentgenogram of the thorax a plum-sized tumour shadow was seen in the right cardiophrenic angle, which was distinct from the heart and adjoined the diaphragm. Pneumomediastinography showed at the 9 to 11 cm planes in the anteroposterior projection and at the 7 to 11 cm planes in lateral projection a dense, sharply circumscribed shadow the size of a small apple, surrounded by a narrow band of gas except where a narrow band-like shadow extended caudally towards, and even beneath, the diaphragm. RD: *Probably infracardial cyst.* The blood picture was: Hb 67, E 4.13 mill., I 0.82, L 4,750, SR 12. Surgical operation was performed on 19 October, 1953: *Thoracotomia l. dx. et exstirpatio cystae* (Dr. PERÄSALO). An egg-sized, saccular, translucent cyst, somewhat adherent to the adjacent structures, was found and dissected from its surroundings, revealing a narrow pedicle between the crura of the diaphragm. Histologic examination: No tumour structures, no inflammation; endothelial tissue, which might be bursal wall, present in one portion of the specimen. Post-operative recovery was uneventful.

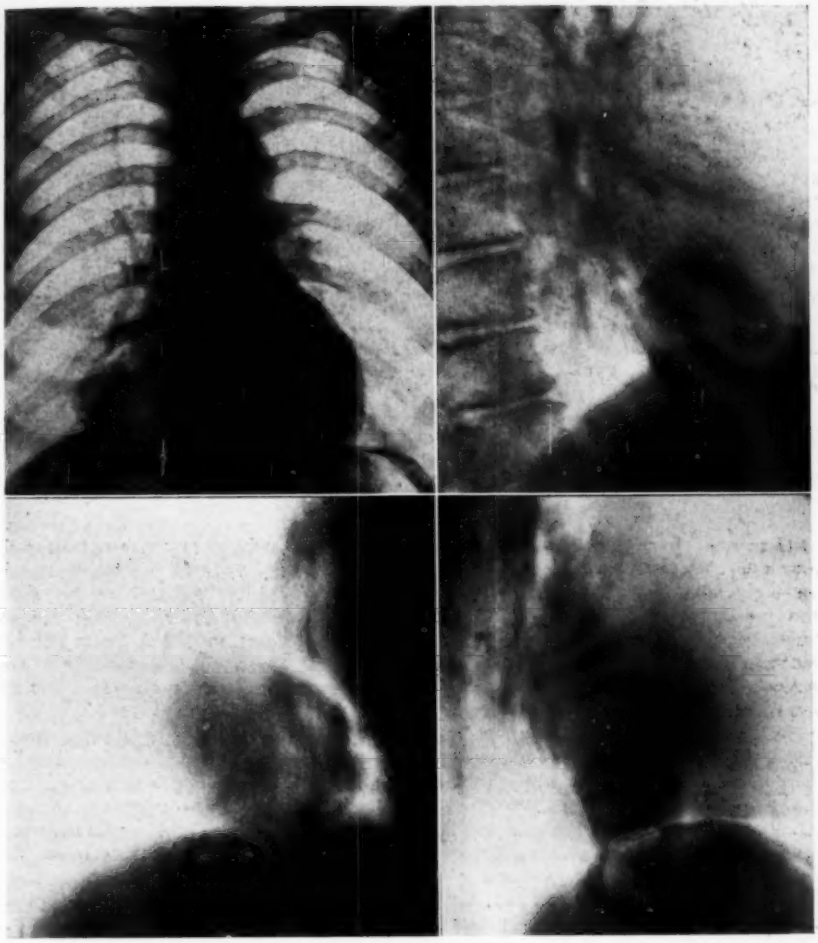
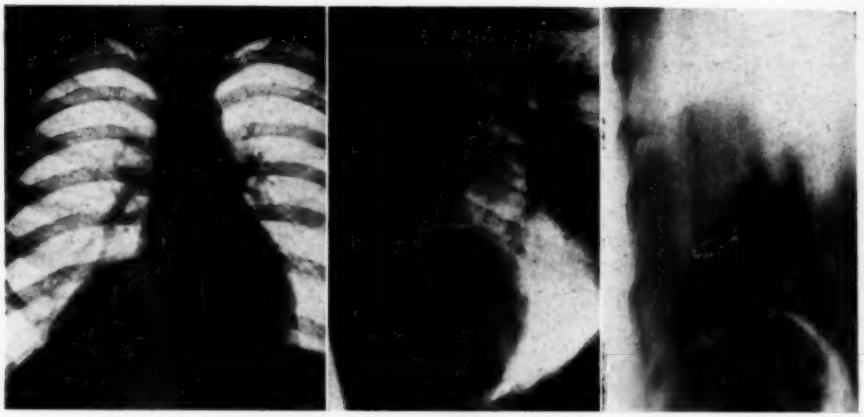


Fig. 2. Case 2. *Top:* Intrathoracic tumour adjoining the diaphragm, found on mass miniature radiography. *Below:* Pneumomediastinogram, gas surrounding the tumour except where a narrow band extends to the diaphragm, originating in the peritoneal cavity with which it is connected by a pedicle.



a. b. c.

Fig. 3. Case 3. a and b. Intrathoracic tumour on the right side revealed by microroentgenography. c. Pneumomediastinogram, gas surrounding the tumour, dorsal surface adjoins the posterior thoracic wall.

Case 3. A truckman, aged 20, had always been in good health and performed heavy work. There had been occasional cough. For the past 3 years he had smoked about twenty cigarettes daily. In October 1953 he was conscripted into military service, where fluorography revealed a shadow in the inferior middle field of the right lung. He was admitted to hospital on 19 November 1953, in good physical condition. Some gurgling râles were heard over the right middle and inferior fields. There was dullness over an area the size of about half-a-palm dorsally in the lower field dextral to the median line. No other abnormal signs. The blood picture was: Hb 77, E 4.42 mill., I 0.88, L 5,050, SR 5. Thorax roentgenography revealed in the lower right field a fist-sized, distinctly circumscribed, evenly shadowed tumour, the dorsal portion of which adjoined the dorsal wall of the thorax and ended below in the cardiophrenic angle. On basis of the tomographic examination it was regarded as probably a tumour originating from the spinal cord. On pneumomediastinography the gas surrounded the medial, caudal and cranial aspects of the shadow. RD: *Neurinoma.* On 26 November a surgical operation was performed: *Thoracotomia l. dx. Exstirpatio tumoris intrathoracalis.* The tumour was sharply circumscribed, of the size of a small fist, and unattached to adjacent structures. Histologic examination: *Neurinoma.* Recovery was uneventful.

In evaluating the results obtained with the pneumomediastinum it should be noted that our series contained, in addition to 'clear' cases, cases which were negative in so far that the gas formed no boundary around the process under examination, or formed such a boundary in some regions only, although the gas otherwise was clearly seen in the mediastinum. The importance of the pneumomediastinum also in these cases should not be underestimated, for it may give an indication of, for

instance, an infiltrative tumour growth. The findings at operation supported this opinion.

The method is a harmless one and technically relatively easily performed. A single praesacral injection of gas offers simultaneous visualisation of both the posterior and the anterior mediastina, which is an advantage not obtained with the so-called direct route methods. The contrast medium around the mediastinal organs given by the pneumomediastinum is a marked improvement in tomographic roentgenography of this area, which otherwise is homogeneous to roentgen rays. Thus gas insufflation and tomography complement each other.

Although the pneumomediastinum, as stated above, is new and still at a fairly experimental stage, the results already obtained are promising and will undoubtedly improve with experience and wider use of the method.

SUMMARY

Thirty patients were subjected to praesacral oxygen insufflation for the production of a simultaneous posterior and anterior pneumomediastinum. This examination is based on the continuity of the pelvic, retroperitoneal and mediastinal connective tissues. In all of these cases it had been impossible to determine with certainty the origin of the process by ordinary radiography and tomography. The pneumomediastinum was combined in all cases with tomography. After a survey of various pneumomediastinal methods and a description of the routes by which the gas enters the mediastinum, three illustrative cases are reported.

ZUSAMMENFASSUNG

Dreissig Patienten wurden einer präsakralen Sauerstoffinsufflation zur Erzeugung eines gleichzeitigen vorderen und hinteren Pneumomediastinums unterworfen. Diese Untersuchung stützt sich auf der Kontinuität des Bindegewebes im Becken, im retroperitonealen Raum und im Mediastinum. In allen diesen Fällen ist es unmöglich gewesen, den Ausgangspunkt des Prozesses mit der üblichen Röntgenuntersuchung und der Tomographie mit Sicherheit festzustellen. Das Pneumomediastinum wurde in allen Fällen mit der Tomographie kombiniert. Nach einer Übersicht über verschiedene pneumomediastinale Methoden und einer Beschreibung der Wege, auf welchen die Luft in das Mediastinum eindringt, werden 3 illustrative Fälle berichtet.

RÉSUMÉ

Trente malades ont subi une insufflation présacrée d'oxygène pour créer simultanément un pneumomédiastin antérieur et postérieur. Cet examen est basé sur la continuité des tissus conjonctifs pelvien, rétropéritonéal et médiastinal. Dans tous ces cas il avait été impossible de déterminer avec certitude l'origine des lésions au moyen de la radiographie simple et de la tomographie. Le pneumomédiastin a été dans tous les cas associé à la tomographie. Après une revue de diverses méthodes de pneumomédiastinographie et une description des trajets par lesquels le gaz pénètre dans le médiastin, l'auteur présente trois observations en exemple.

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THE PRINCIPLES OF THE CONSTRUCTION AND FUNCTION OF THE STEREO-PANTOMOGRAPH

A Device for Stereoscopic Pantomography with a Single Exposure

by

Yrjö V. Paatero

I recently published a preliminary report (9) on a new method based upon the principles of pantomography. The method makes it possible to obtain stereoscopic roentgenograms of curved layers with a single exposure without the conventional tube-shift and cassette change. The construction and function of the device, the stereo-pantomograph, designed for realizing the method, particularly in jaw roentgenography, will be outlined in this paper.

As several articles on pantomography have already been published (5, 6, 7, 8, 9, 10), I shall avoid repetition of the matter previously treated. At the same time, I would refer to two authors who have pointed out the great significance of the employment together of a given movement and narrow roentgen beam.

MILLWEE (4) has designed an apparatus for roentgenography of the spine, in which a roentgen tube with a narrow beam moves horizontally and projects the whole spinal column on a single film. This method has also been utilized for another purpose.

HECKMANN (2), also considered the slit method advantageous in spinal roentgenography. In addition, he described several ways of eliminating undesirable shadows by using a narrow roentgen beam together with a suitable movement, and of representing the whole outer layer of a roundish object.

As to the principles of stereoscopic roentgenography in general, I would refer the reader to HASSELWANDER (1).

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I have developed pantomographic roentgenography in accordance with the fact that *a moving film picks up a sharp representation only of that surface of a rotating object which moves with an equal linear velocity to the film, because the said surface is stationary in relation to the film when*

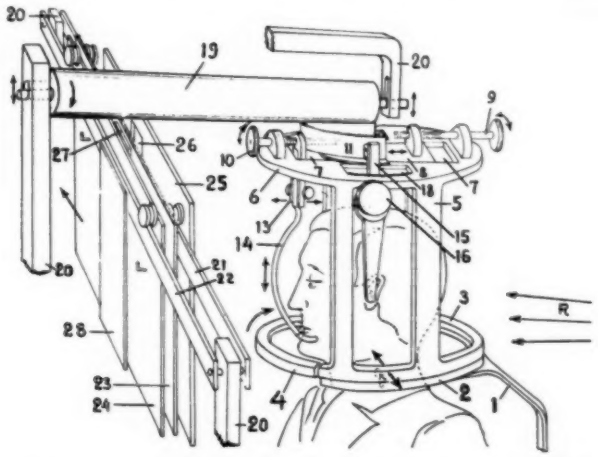


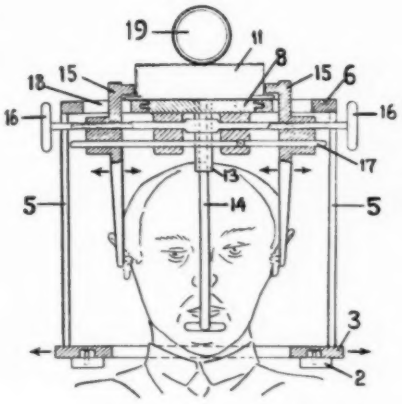
Fig. 1. The stereo-pantomograph seen from the side in perspective. Right: Cephalostat with the patient immobilized. Left: Movable cassette holder system.

passing a narrow roentgen beam. All other parts of the object move faster or slower than the film and cannot, therefore, be projected sharply on the film; only soft lines or even no tracks at all of these will appear. Pantomography is thus not only a method of representing the outer surfaces or layers of objects but any curved outer or inner layers of an object may be projected.

Since the pantomographic representation, called a pantogram, has always some depth, it is also possible to obtain tri-dimensional views with the method. Hence, if desired, the entire curved layer may be roentgenographed stereoscopically. The procedure may be carried out with a single exposure without the conventional tube-shift and cassette change. Certain necessary apparatus, however, is needed; this I have recently designed and its construction and function will now be explained.

The stereo-pantomograph consists of a rotating chair, two movable cassette holders with their supports and a power transfer roller. In addition to these principal parts, certain fittings, such as an immobilisator, a speed regulator, etc. are required. I shall ignore the lower parts of the machinery and deal exclusively with the upper parts, which actually

Fig. 2.



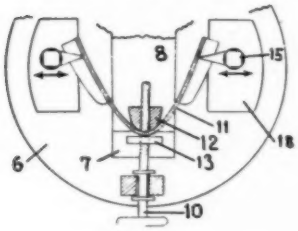


Fig. 3.

Fig. 2. The immobilization and cassette speed regulating mechanism from the front.

Fig. 3. The cassette speed regulating mechanism from above.

form the heart of the stereo-pantomograph. These are schematically depicted in Figures 1, 2 and 3.

In Fig. 1, the stereo-pantomograph is seen from the side in perspective, in Fig. 2 from the front, while Fig. 3 shows the cassette speed regulating mechanism from above. As the corresponding parts in each drawing are identified by the same number, it will be unnecessary to refer to the individual figures in the description which follows.

An arm of rigid construction (1) is attached to the chair, and to the upper end of which a ring (2), open in front, is attached. Another ring (3), with a detachable front part (4) to admit the patient's neck, is fixed to this first ring. The second (or upper) ring may be moved a few centimeters to the right or left in order to obtain an eccentric position. The first (or lower ring) (2) is stationary and concentric to the rotational axis.

A so-called 'cephalostat' (KOSKI 3), with an immobilizating mechanism is attached to the upper ring. An automatic cassette speed regulating mechanism, which makes the use of the device very simple, is also incorporated. The top of the cephalostat (6) is supported by four vertical arms (5) on the ring (3); in it there is an opening (7) in which the slide (8) can be moved sagittally by turning a screw (9). There are two further openings (18) in the top, through which the upper ends of the ear rods (15) reach up and in which they can be moved in any direction. By turning the screw rod (16) in the slide, the ear rods may be moved closer or further apart. Another and stationary rod (17) for guiding the ear rods, lies below the screw rod.

A cassette speed regulator spring (11), the shape of which corresponds approximately to that of the human jaw, is fixed on the top. The shape and positioning of the spring is adjustable, as we shall see later. A nut (12) is attached to the front part of the spring. By turning the screw

(10), both the spring and the chin support (14) may be shifted sagittally. The chin support is movable vertically in the flat tube (13) which is also attached to the spring. A horizontal pin fitting for immobilizing the patient's chin lies at the lower end of the chin support. The pin and the front of the spring must always be equidistant from the rotational axis.

The movement of the rotating spring is transferred by the roller (19) to the cassette holders (23 and 24), which may be moved linearly. Both ends of the roller may be raised at the support arms (20) to allow the spring and cassette holders to move freely when the patient is being immobilized in the chair. In order to assure good friction, the roller is covered with rubber or a similar substance and the upper edges of both the spring and the front cassette holder (23) are roughened. Because of the divergence of the roentgen rays, the roller (19) must be slightly conical in shape in order to give the cassette holders a somewhat greater linear speed than the spring and the corresponding jaw. The cassette system shown in Fig. 1 is situated, for the sake of clarity, further from the cephalostat than it would be in practice when the cassette holders move close to the object.

In addition to the cephalostat, the cassette system is an essential feature of the stereo-pantomograph. Two horizontal tracks (21, 22) are attached to the vertical support arms (20). The cassette holders may be moved along the tracks on small wheels. The holders may be thin sheets of wood or just plain frames to which the cassettes are fastened during the exposure.

The upper edge of the front holder (23) is the only portion which needs to be roughened, since the roller engages with it. The back holder (24) may be joined with the former with which it will then move.

A stationary lead sheet (25) in front of the cassette holders protects the films from secondary radiation. A vertical slit (26) is provided in the lead sheet, through which the narrow roentgen beams are directed onto the films. A second fixed lead sheet (28) stops the roentgen rays behind the cassettes. A third stationary lead sheet (27) is situated between the cassette holders, the purpose of which is to cut off one of the two beams before the back cassette. As explained in my preliminary report (9), two narrow roentgen beams, side by side, are used in taking stereo-pantomograms with a single exposure. One of the beams will produce a picture on the front film and the second on the back film. The two pantomograms are projected from slightly different viewpoints and blend together when seen stereoscopically. As the beam reaching the back film must first penetrate the front film, it is necessary to lessen the intensity of this beam. There will thus be practically only one eccentric projection on the front film. On the other hand, the relative sensitivity

of the back film should be increased. There are various ways of accomplishing this correction. For instance, in the front cassette only one intensifying screen may be used, while the back cassette may be furnished with conventional double screens.

Fig. 4. Stereoscopic lateral views of a dry skull taken with a single exposure.

The procedure in taking pantomograms is as follows: The chair should first be turned so that its sagittal plane is roughly parallel with the cassette holders. The patient is then so placed into the chair that the auditory meatuses are approximately at the height of the ear plugs at the lower ends of the ear rods. By turning the screw rod (16), the ear plugs are introduced into the external auditory meatuses. As the ear rods approach each other, they simultaneously bend the spring until its width corresponds to the distance between the condyles. The chin support should then be adjusted so that the short pin at its lower end slightly presses the chin. This is done by turning the screw (10) at the top of the cephalostat. This screw also pushes the spring again correspondingly backwards. After the immobilization, the shape and situation of the spring correspond very nearly to those of the jaws. The roller must, of course, be lifted during the adjustment.

Provided that the cassette holders with the cassettes are at the starting ends of the tracks, the exposure may now take place and the apparatus functions. While the chair rotates, the spring makes the roller revolve at a linear speed equal to that of the spring and the jaws as these pass the roentgen beams. The roller also moves the cassette holders with the cassettes at every point at a correct velocity. The films are thus stationary to the area and layer of the object which is to be pantomographed and the films collect a pair of stereo-pantomograms, in this case, of the jaws.

Fig. 4 represents stereoscopic lateral views of a dry skull taken with a

prototype apparatus. Both films were exposed simultaneously, as explained above.

If stereo-pantomograms are not required, only a single beam may be used, advantageously, through the imaginary rotation axis. If, further, two separate layers are to be obtained, the cassette holders may be moved at different speeds.

I hope to return to the problems involved as soon as the new apparatus is completed and sufficient experiments have been performed with it.

Aeknowledgement

This work has been financially supported by the Sigrid Jusélius Foundation (Sigrid Jusélius Stiftelse), and the Cultural Fund of Finland (Suomen Kulttuurirahasto), Helsinki, to which I acknowledge indebtedness.

SUMMARY

The apparatus described enables the stereoscopic recording on flat films of the curved outer and inner layers of objects with a single exposure and without the conventional roentgen tube-shift and cassette change.

The theory and practical application of the apparatus which has been developed by the author are discussed in detail.

ZUSAMMENFASSUNG

Der beschriebene Apparat ermöglicht die stereoskopische Registrierung an gewöhnlichem planem Röntgenfilm der gekrümmten äusseren und inneren Konturen von Objekten mit einer einzigen Exponierung und ohne die übliche Verschiebung der Röntgenröhre sowie ohne Kassettenwechsler.

Die Theorie und die praktische Anwendung des vom Verfasser konstruierten Apparates werden ausführlich besprochen.

RÉSUMÉ

L'appareil décrit permet la représentation stéréoscopique sur films plans de couches courbes externes et internes d'objets par une seule prise de cliché et sans les habituels décalage du tube et changement de cassette.

L'auteur étudie en détail la théorie et l'application pratique de l'appareil qu'il a mis au point.

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9. — Stereoscopic Roentgenograms with a Single Exposure. (Primary Report). Suom. hammaslääk. toim. 49 (1953), 239.
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Addendum

After this article was submitted for publication, the following papers have been published:

Duhamel, J.: Les procédés de radiographie en coupe non rigoureux. Sci. Indust. phot. 25 (1954), 129.
— Une forme nouvelle de phototomographie. La photopantomographie de Y. V. Paatero. Sci. Indust. phot. 25 (1954), 353.
Paatero, Y. V.: Theoretico-Experimental Study on the Origin of the Stereoscopic Effect in Pantomography. Suom. hammaslääk. toim. 50 (1954), 193.

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NOMOGRAM FOR ESTIMATION OF THE HEART VOLUME

by

Ragnar Hol and *Bjørn Thalberg*

Whenever numbers are to be put into the same formula several times a day there is a definite demand for a suitable nomogram.

For estimation of the heart volume per square metre body surface in diagnostic radiography the formula:

$$V = \frac{l \cdot b \cdot d}{\text{square m. body surface}} \cdot K$$

is generally used (JONSELL 1939). Here l, b and d stand for the length, breadth and depth of the approximately elliptical shadow of the heart in the roentgenograms. The factor K depends upon the size of the heart and the degree of magnification in the film. Except for exceptional cases, such as an extremely large heart, a constant value for K may be used.

There are thus four numbers to be multiplied, and the result is divided by a fifth, the total square metre body surface.

Multiplications may be made easily by drawing lines across a certain parabola. The very simple construction of this parabola is illustrated in Fig. 1. Its mathematical equation is $y = x^2$. A num-

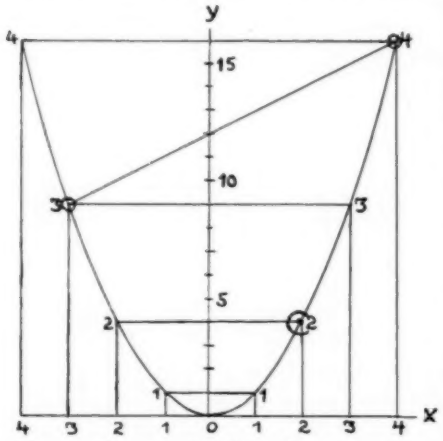

Fig. 1. The construction of a nomogram for multiplication and division.

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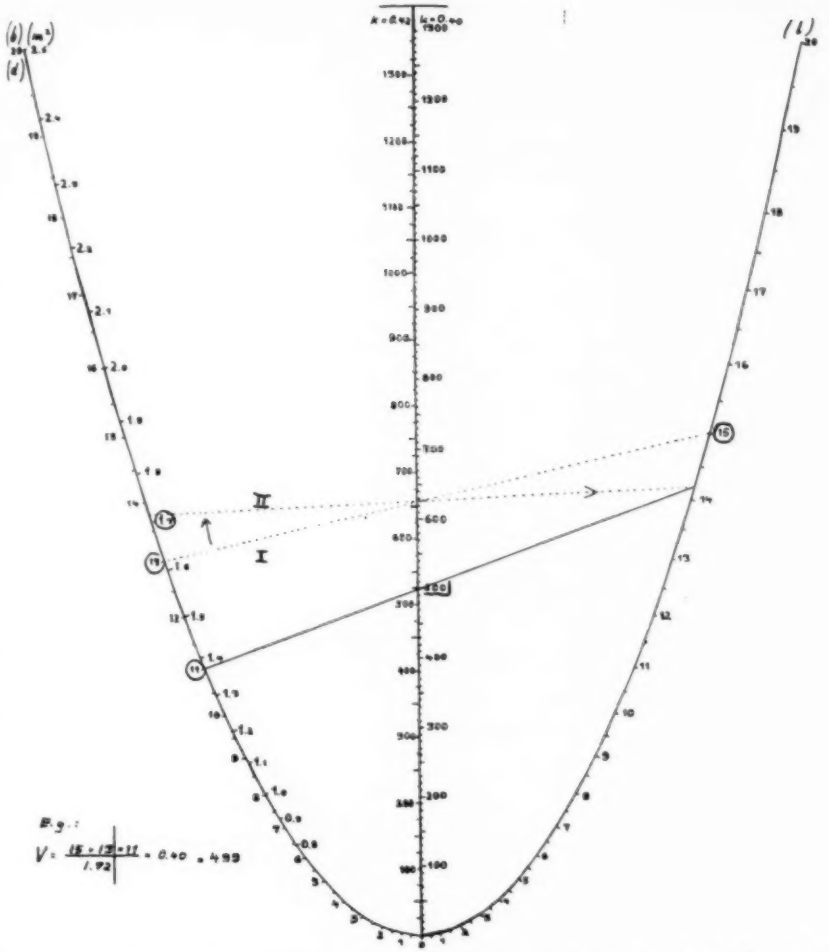

Fig. 2. Nomogram for estimation of the heart volume per square metre body surface.

ber, for instance 2, on the x-axis is squared, which makes 4; this determines point 2, marked in Fig. 1 with a circle, on the right branch of the parabola.

A straight line, drawn from a selected point (number) on one side of the parabola to a selected point on the other side cuts the mid-axis (y-axis) at a point where we read the product of the two numbers selected, *e. g.* if we choose the numbers 3 and 4, we read 12 on the mid-axis.

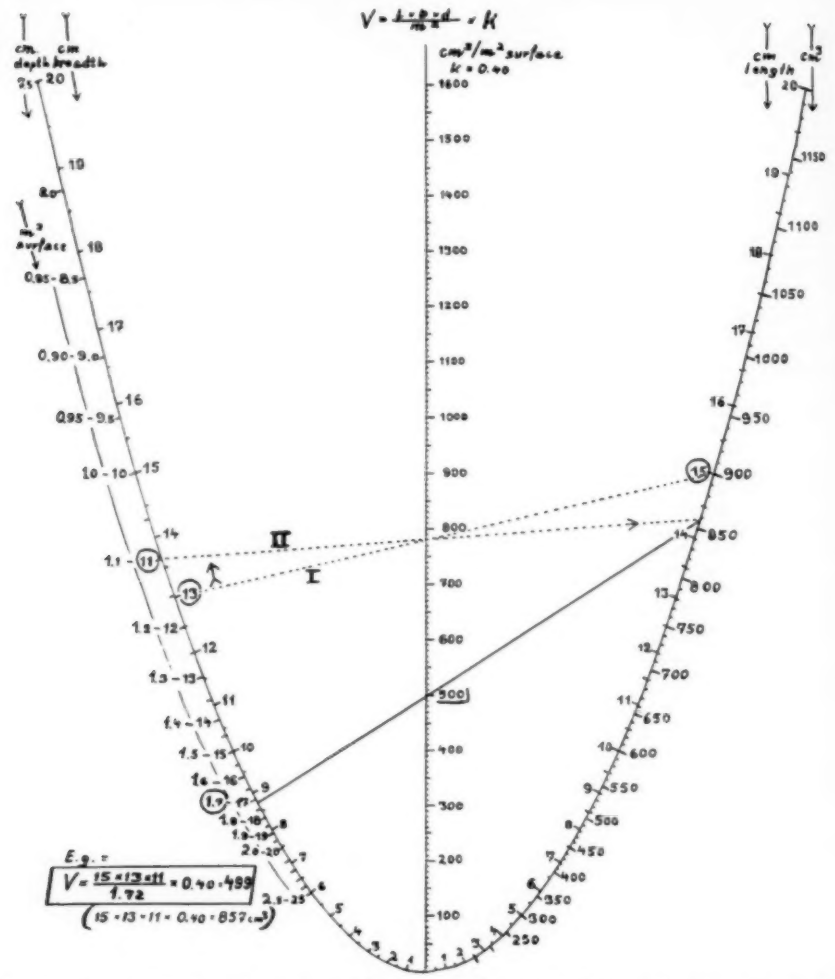

Fig. 3. Nomogram for estimation of the heart volume in cubic centimetres, and cubic centimetres per square metre body surface.

We may also carry out divisions by placing the dividend on the mid-axis and the divisor on one of the branches of the parabola. A straight line drawn between these points will cut the other branch at a point where we read the quotient.

In the nomogram (Fig. 2), we start with the multiplication of length and breadth (in our example 15 cm and 13 cm) by connecting these

points with the dotted line I. In order to avoid too large figures we now divide the result with the square metre body surface (1.72) by drawing line II through the point where the first line intersects the mid-axis. From the point where line II cuts the right branch of the parabola we have drawn a line to the point corresponding to the value to the depth (11 cm) on the left branch. Where this line meets the mid-axis we read the final result. The values on the mid-axis are multiplied with the factor K beforehand.

Two alternative values for K are given in Fig. 2; one scale to the left where the factor is 0.42 and one scale to the right where K is 0.40.

It may be of interest to estimate not only the volume of the heart in cubic centimetres per square metre body surface, but also the volume in cubic centimetres. In the latter case we have to make three successive multiplications. We have therefore constructed another nomogram based on the same principles (Fig. 3). As in Fig. 2, line I gives the multiplication of length and breadth ($15 \cdot 13$). In order to simplify the operation, we now divide this product with the inverse fraction of the depth $\left(\frac{l}{d}\right)$. The scale for $\frac{l}{d}$ — expressed in d — is written on the left-hand side of the left branch of the parabola. Thus we draw line II and read the result on the right branch of the parabola, where the scale already is adjusted for a multiplication with the factor $K = 0.40$. We finally find the volume in cubic centimetres per square metre body surface by multiplying the result we have on the right branch of the parabola with the inverse number for total body surface (in the example 1.72) as shown in the figure.

In dealing with very large hearts, the right branch of the parabola in Fig. 3 must be extended.

The above methods produce theoretically accurate results; how good these will be in practice will depend upon the size of the nomograms constructed. The methods may, however, even with fairly small nomograms, give quite good approximations (cf. Figs. 2 and 3), and the operations are quick and simple.

SUMMARY

The construction of a nomogram for multiplication and division is described. Its application to the formula for the estimation of the heart volume per square metre body surface is shown.

ZUSAMMENFASSUNG

Die Konstruktion eines Nomogrammes für Multiplikation und Division wird beschrieben. Die Benutzung des Nomogrammes für die Formel zur Berechnung des Herzvolumens pro Quadratmeter Körperoberfläche wird beschrieben.

RÉSUMÉ

Les auteurs décrivent la construction d'un abaque pour la multiplication et la division et montrent son application à la formule qui donne le volume cardiaque par mètre carré de surface corporelle.

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ESTIMATION OF THYROID VOLUME

An anatomic study of the correlation between the frontal silhouette and the volume of the gland

by

Erkki Himanka and *Lars-Gunnar Larsson*

When a patient is treated with radioactive iodine, the irradiation dose delivered to the thyroid will be inversely proportional to the thyroid volume. All pretreatment examinations must therefore include a more or less accurate estimation of this factor. Three types of investigations give information about the size of the thyroid:

1. *Clinical examination.* In patients with enlarged, easily palpable thyroid glands an experienced examiner may estimate the thyroid volume with some accuracy. In a series reported by SOLEY et coll. (13) the thyroid weight was clinically estimated before thyroidectomy; 25 per cent of the estimations fell within 10 per cent of the actual weight, while in the remaining cases errors up to about 40 per cent were observed. It is probable that the errors are often larger, especially with less experienced examiners. The convertion of the clinical finding to a weight or volume may be facilitated by the use of thyroid models of different sizes (14, 10), and the accuracy may increase somewhat if the mean of several estimations performed by different examiners is used. In many cases, especially those with small glands, recurrences after previous operations, or fat necks, the clinical estimation of the volume is often extremely inexact and, in cases with intrathoracic goiter, quite impossible.

2. *Roentgenogram.* When the goiter is localized to the neck, roentgenologically observed compression or displacement of the trachea or oesophagus may give some additional information as regards the thyroid size. In the case of an intrathoracic goiter a roentgenogram of the chest often gives a good idea of its size.

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3. *Gammagram.* After a tracer dose of radioactive iodine (I^{131}) the irradiation from small portions of the thyroid may be registered by a suitable collimated measuring instrument and it is also possible to delineate different projections of the thyroid. Several types of directional Geiger-Müller counters were constructed, and methods for *in vivo* determination of the thyroid volume were also worked out (10, 5). Due to the low gamma-sensitivity of the G.-M. counters the collimators must be relatively wide and the demarcation obtained was unsharp. With the introduction of gamma-sensitive scintillation counters (6, 7, 9), much better possibilities were obtained for 'scanning' of the activities in the thyroid after a tracer dose as well as for the delineation of the thyroid silhouette (1, 2, 3, 4, 8).

By the use of a directional scintillation counter, ALLEN and GOODWIN (1) stated that the thyroid volume could be estimated from the frontal scintigram with an average error of only 10 per cent, and the maximal error in the series examined was 25 per cent. A simple formula was used for the calculation. With due consideration to the large anatomic variations of the thyroid shape it seems astonishing that such high accuracy could be obtained by the use of only one projection. The errors when the thyroid volume is estimated by the frontal scintigram may be divided into two groups:

a. *Anatomic variations in the thyroid shape.* If all thyroid glands had a uniform shape an exact correlation could be found between the anatomic frontal projection and the volume of the gland. The shape of the thyroid, however, shows large variations.

b. *Discrepancies between the frontal scintigram and the true anatomic frontal silhouette.* By using an infinitely narrow collimator precise outlining of the thyroid could be performed. In practice the exactness of the scintigraphic silhouette varies with the width and length of the cylindric collimator and with the distance between the crystal and the irradiation source.

In the previously quoted investigation by ALLEN and GOODWIN (1) the accuracy of the method was tested by direct comparison of the frontal scintigram and the thyroid weight found at operation or necropsy. It appeared, however, of interest to study the error due to the anatomic variations alone and that was the aim of our investigation. At 44 necropsies the neck organs including the thyroid were removed in one portion and fixed in formalin. After fixation, the thyroid, larynx and trachea were dissected free from their surroundings, the thyroid being left in its original position around the trachea. The preparation was placed on paper and the frontal outline marked by pins placed sagittally. In order to obtain the true silhouette, the same procedure was performed both

from the anterior and the posterior aspects. The thyroid was then removed and its volume determined by fluid displacement. The frontal silhouettes with the corresponding volumes are illustrated in Fig. 1.

Fig. 1. The anatomic frontal silhouettes with the corresponding thyroid volumes.

To obtain a linear correlation with the volume (V) some data derived from the frontal silhouette must be converted to the dimensions of a volume. If only the area (A) of the silhouette is used, the simpliest correlation will be:

$$V = k_1 \cdot (\sqrt{A})^3 \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (1)$$

Other expressions may also be used as, for instance,

$$V = k_2 \cdot A \cdot L \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (2)$$

where L is the average length of the thyroid lobes. The last formula was used by ALLEN and GOODWIN.

In our series the average for k_1 was 0.33 ± 0.06 and the average for k_2 was 0.27 ± 0.06. The average error for the individual observation was thus with both methods about ± 20 per cent and the maximal error observed in this series, about 40 per cent. As the length of the lobes was not always well defined in the frontal silhouette (Fig. 1) we prefer expression 1 and the correlation obtained with this method is illustrated in Diagram 1. To facilitate the practical calculation of the volume from the area of the silhouette the simple nomogram in Diagram 2 was constructed.

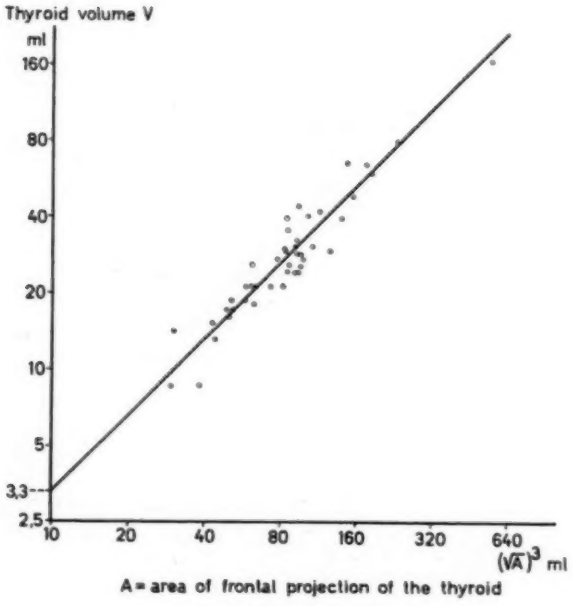

Diagram 1.

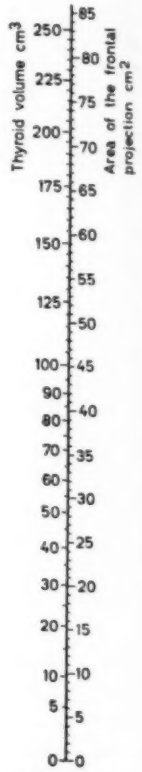

Diagram 2.

Diagram 1. Correlation between the thyroid volume and the expression $(\sqrt{A})^3$ where A is the area of the frontal silhouette. Due to the logarithmic scale the 45° line represents a linear correlation.

Diagram 2. Nomogram for the calculation of the thyroid volume from the area of the frontal silhouette.

Discussion

The error in our series was considerably larger than in the series published by ALLEN and GOODWIN despite the fact that our error mainly included the anatomic variations and not discrepancies between the frontal scintigram and the true frontal silhouette of the gland. It is also probable that the average error would be even larger in a series containing thyroid glands of highly atypical shapes as a result, for instance, of recurrent hyperthyroidism following previous operations. It seems obvious that the estimation of thyroid volume from the frontal scintigram must be relatively inexact, and that the accuracy of the method was somewhat over-estimated by the first investigators (1). The same opinion was expressed in a paper recently published by KELLY (11). Due to the complicated shape of the thyroid it seems, however, difficult to find a more accurate, simple scintigraphic method for the determination of the thyroid volume. Owing to the overlapping of the two lobes, oblique and lateral projections are usually difficult or impossible to interpret.

A somewhat rough estimation is, however, often better than no estimation at all, and the frontal scintigram without doubt gives valuable information concerning the thyroid size in many cases in which the gland is impossible or difficult to palpate. The method has been used in our laboratory for such cases during the last year. In some cases of primary and recurrent hyperthyroidism the thyroid gland was found to be astonishingly small, and overdosage could be prevented by employing a scintigram. In patients with easily palpable glands, the clinical estimation probably gives quite as good or even better results but in these cases the scintigraphic outlining may serve as a control. For the study of the distribution of I^{131} in the thyroid, the scintigram is, of course, extremely useful.

When patients with diffuse toxic goiters are treated with radioactive iodine it is important to realize the dosage determinating factors as thyroid uptake, effective half-life of I^{131}, and thyroid volume, and the determination of these factors after a tracer dose may serve as a guide for the management of the treatment. It has, however, always been the opinion in our laboratory (12) that the dosage determinations in these cases are not sufficiently precise to serve as basis for a critical analysis of treatment results, and this view has not been altered by the introduction of frontal scintigrams for the estimation of thyroid volumes.

SUMMARY

The correlation between the frontal projection and the volume of the thyroid gland was studied in 44 necropsy cases. The method employed is described. The average error

for the determination of the thyroid volume from the frontal silhouette of the gland was found to be about ± 20 per cent and the maximal error observed about 40 per cent. It appeared from the investigation that the method of estimating the thyroid volume from the frontal scintigram must be less exact than has been previously stated.

ZUSAMMENFASSUNG

Die Beziehung zwischen der Frontalprojektion und dem Volumen der Glandula thyreoidea wurde an 44 Leichen studiert. Die benutzte Methodik wird beschrieben. Der Durchschnittsfehler für die Bestimmung des Thyreoideavolumens aus der Frontalsilhuette der Drüse wurde um etwa ± 20 % gefunden und der maximale Fehler bei etwa 40 %. Aus der Untersuchung scheint hervorzugehen, dass die Methode der Schätzung des Thyreoideavolumens aus dem frontalen Scintigramm weniger genau ist als man bisher angenommen hat.

RÉSUMÉ

La corrélation entre la projection frontale et le volume de la glande thyroïde a été étudiée sur 44 cas autopsiés. La méthode employée est décrite. L'erreur moyenne sur la détermination du volume de la thyroïde à partir de sa projection frontale s'élève à ± 20 pour cent, et l'erreur maximum observée a été d'environ 40 pour cent. Il ressort de ces recherches que la méthode d'estimation du volume de la thyroïde à partir du scintigramme frontal doit être moins précise qu'on ne l'avait précédemment affirmé.

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THE USE OF COLLOIDAL Au^{198} FOR THE DETECTION OF LYMPH NODES IN RADICAL EXCISION OF THE BREAST

by

K. A. Hultborn and *L. I. Jonsson*

The importance of adequate removal of regional lymph nodes in the treatment of some types of cancer has long been recognized. MONROE (1948) presented the results of his studies on mammary cancer operative specimens which had been cleared and from which all lymph nodes had been dissected out and charted. A comparison was made between the work of individual operators and between the numbers of lymph nodes present in each of the specimens in relation to the number of five-year cures. The investigation suggested that the greater the number of lymph nodes removed in the operation specimen, the greater were the patient's chances of freedom from recurrence. This applied to both Stage I and Stage II cases, *i. e.*, cases without and cases with demonstrable axillary lymph-node metastases. SPRONG and POLLOCK (1951) reported the results of a similar investigation, which were fully consistent with the above.

In an editorial in the A.M.A. Archives of Surgery, March 1954, ELMAN discussed the above-mentioned studies under the heading: "Unnecessary Surgery and Inadequate Surgery." Having in mind the fact that radical excision of the breast evidently varies with regard to the adequacy of such an essential feature as axillary dissection, he writes: "What is shocking, therefore, is to realize that patients with cancer of the breast are still being subjected to an inadequate operation which can only shorten their maximum span of life and thus needlessly increase cancer mortality. It seems wasteful and myopic to expend so much effort on

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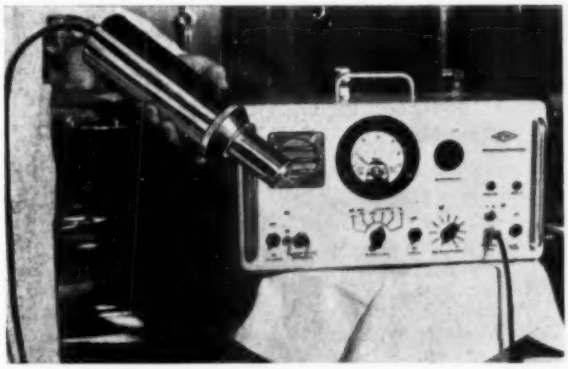

Fig. 1. The directional scintillation counter for use during operation.

programs to detect cancer early without at the same time taking measures to ensure its adequate removal." In his opinion, counting and charting of lymph nodes is one available method of measuring the adequacy of the operation. Even if time-consuming techniques of examining specimens are required to make such studies, the potential rewards to the patient are so great as to make the effort worth while.

In a functional anatomic study of the lymph drainage from the breast, HULTBORN et coll. (1954) used colloidal radiogold (Au^{198}). This isotope has a half-life of 2.7 days and is both a β- and γ-emitter. A tracer dose was injected into the breast in cases with mammary carcinoma 1 to 10 days before radical excision. The transport of the isotope could then be studied *in vivo* with a directional scintillation counter, and was also studied in the operative specimens by direct measurements and radioautography. The colloidal radiogold was partly transported to the lymph nodes and deposited there, while only very small amounts could be found in the surrounding tissues containing the lymph vessels. In some cases, small lymph nodes could be found only with the guidance of a radiation detector on dissection. The idea then arose of using a scintillation detector during the course of operations, by means of which it might be possible to detect and remove a greater number of nodes than would otherwise be the case. Lymph nodes totally involved by metastases are naturally devoid of function and cannot take up the colloid; yet we observed uptake not only in nodes with small cancer foci but also in extensively involved nodes with only small remnants of normal lymphatic tissue. We also found that in some cases not all the normal axillary lymph nodes took up the radiocolloid. Probably different parts of the breast drain to different lymph nodes in the axilla. Another possible explanation may be that some axillary lymph nodes are arranged in a series, where only the first node receives direct lymph vessels from the breast and takes up the

Fig. 2. The scintillation counter in use in the deep part of the axilla.

colloid. We did find, however, that all normal lymph nodes showed uptake when an extensive part of the breast was infiltrated with the colloidal radiogold. At all events, there was sufficient reason to suppose that injection of the isotope and use of a scintillation counter during operation would help to ensure adequate dissection of the lymph nodes.

For use during operation a movable γ-sensitive directional scintillation counter with a NaI (Tl) crystal was constructed. The counter was provided with a cylindrical collimator with a length of 3 cm, an aperture diameter of 1.5 cm and a lead thickness of 1.2 cm (Fig. 1). To facilitate monitoring of the radioactivity during the operation, acoustic registration of the impulses was used. The apparatus and its lead shield were enclosed by a long sterile hood and the cylindric collimator by an operation glove, fixed with rubber bands. In this way, sterility was not jeopardized (Fig. 2).

The following data are referable to three cases investigated so far.

Case 1. 62-year-old woman with a walnut-sized carcinoma in the upper lateral quadrant of the left breast. Preoperative roentgen treatment was given. On 19 May, 1954, a subareolar injection of 3 mC colloidal Au^{198} was given. On 21 May, radical excision of the breast was performed (ARNER). When the operator considered the dissection of the axilla to be complete, the scintillation counter was used. It demonstrated high counting rates in a circumscribed area of the axilla high up, medially, beneath the clavicle. The tissue in this area was removed. The pectoralis minor was transplanted to the axilla *ad modum* Heile. No localized uptake could be demonstrated in that muscle.

Quantitative determination of the uptake of Au^{198} in the operative specimen gave the following results, expressed in per cent of the amount injected (correction for physical decay).

Axillary nodes, dissected from the specimen	3.5	per cent.
Axillary tissue after removal of the lymph nodes	0.17	» »
Axillary nodes revealed by the scintillation counter and removed at operation	0.06	» »

The microscopic examination revealed several normal lymph nodes in the axilla but no metastases. The tissue removed with the guidance of the scintillation counter contained three small lymph nodes, all with an uptake of radiogold (Fig. 3).

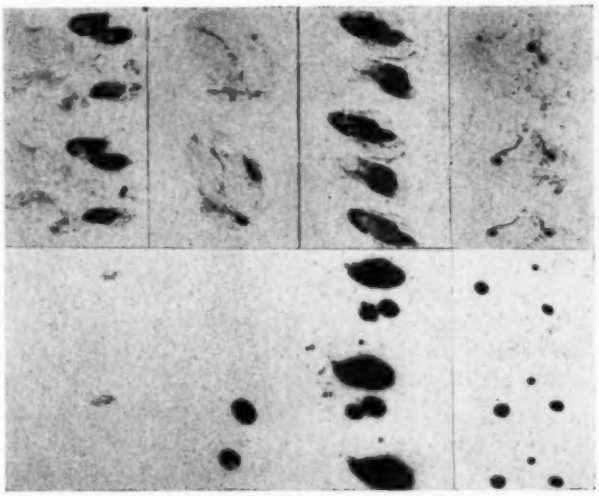

Fig. 3. Case 1. Axillary lymph nodes removed at radical excision of the breast. (Stained section above, radioautographs below.) The three small lymph nodes with uptake on the right slide were detected at operation with the guidance of the scintillation counter, when the operator regarded the dissection as complete.

Case 2. 62-year-old woman with an almond-sized carcinoma in the upper lateral quadrant of the right breast. Preoperative roentgen therapy was given.

A subareolar injection of 3 mC Au^{198} was given on 24 May, 1954. Radical excision of the breast was performed on 26 May (SCHREEB). When the operator considered the dissection of the axilla to be complete, the scintillation counter was used. It disclosed high counting rates in a circumscribed area high up, medially, in the axilla. The tissue was excised.

Quantitative determination of the uptake in the operative specimen gave the following results (correction for physical decay).

	Per cent Total	Per cent/gram tissue
Axillary nodes dissected from the specimen	16	3.8
Axillary tissue after dissection of the nodes from the specimen	0.03	0.001
Axillary lymph nodes, revealed by the scintillation counter and removed	0.39	0.49
Tissue around the above-mentioned nodes that was removed with guidance of the counter	0.005	0.001

Microscopy revealed several normal lymph nodes in the axilla but no metastases. The tissue removed with the guidance of the counter contained five small normal lymph nodes, all with an uptake of radiogold (Fig. 4).

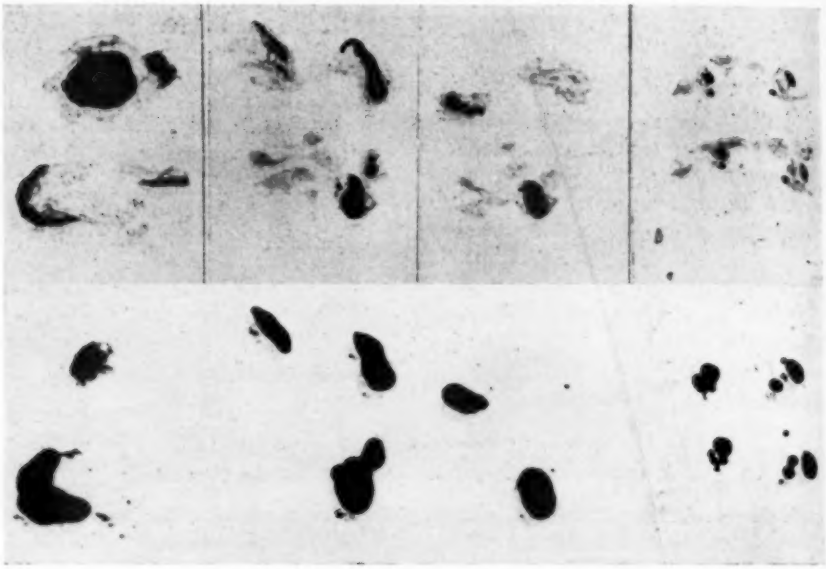

Fig. 4. Case 2. Axillary lymph nodes removed at radical operation of the breast. (Stained section above, radioautographs below.) The five small lymph nodes on the right slide were detected at operation with the guidance of the counter, when the surgeon had finished his dissection.

Case 3. 47-year-old woman with a walnut-sized carcinoma in the upper lateral quadrant of the left breast. Preoperative roentgen therapy was given. A subareolar injection of 1 mC Au^{198} was given on 26 May, 1954, and radical excision of the breast was carried out on 2 June (ARNER). When the operator considered the dissection of the axilla to be complete the scintillation counter was used. No localized uptake could be demonstrated in the axilla, nor in the divided pectoralis minor.

Quantitative measurement of the uptake of radiogold in the operative specimen gave the following results (correction for physical decay).

	Per cent Total	Per cent/gram tissue
Axillary nodes dissected from the specimen	17	2.8
Axillary tissue after removal of the lymph nodes from the specimen	0.1	0.002

The operation had been in progress only 30 minutes when the counter was used, and yet no persisting lymph nodes could be found. The histologic examination showed that 48 nodes were removed from the axillary tissue, and 39 of these nodes revealed an uptake of radiogold (Fig. 5). No metastases were found.

We were thus able in two of the three cases to detect and remove further lymph nodes after the operator had concluded his dissection of

Fig. 5. Case 3. After 48 lymph nodes were removed at radical excision of the breast, 39 showed an uptake of radiogold. (Stained section above, radioautographs below.) No further lymph nodes could be found with the scintillation counter when the surgeon had finished his dissection of the axilla.

the axilla. In the third case, however, we were unable to demonstrate any localized uptake in the axilla when the dissection was concluded. In two cases which underwent operation *ad modum* Heile with transplantation of the pectoralis minor, no uptake was detected within that muscle.

It seems quite probable that the technique described or some modification of it, may serve as a valuable adjunct in radical removal of the axillary lymph nodes. With the Au^{198} activity used, no appreciable irradiation hazards to the surgeon's hands seem to occur, as was verified by practical protection measurements using film and ionization chambers, and with regard both to the β- and γ-dose.

SUMMARY

In three cases of mammary carcinoma a tracer dose of radioactive colloidal gold was injected into the breast some days before radical excision. When the surgeon considered the dissection of the axilla to be complete, it was possible in two of the cases to detect further lymph nodes in the axilla with a directional scintillation counter. It is suggested that the technique described, or some modification of it, may be a valuable adjunct for detection of lymph nodes during operation.

ZUSAMMENFASSUNG

In 3 Fällen mit Mammakarzinomen wurde einige Tage vor der radikalen Exzision eine Spurdosis radioaktiven kolloidalen Goldes in die Brust injiziert. Nachdem der Chirurg die Ausräumung der Achselhöhle als vollständig beurteilt hatte, war es in 2 der Fälle möglich, mit einem Szintillationszähler weitere Lymphdrüsen in der Axille zu entdecken. Es wird angedeutet, dass die beschriebene Technik oder eine Modifikation derselben ein wertvolles Hilfsmittel zur Entdeckung von Lymphdrüsen während der Operation sein kann.

RÉSUMÉ

Dans trois cas de cancer du sein une dose traceuse d'or colloïdal radioactif fut injectée dans le sein quelques jours avant l'exérèse radicale. Quand le chirurgien pensa avoir fait une dissection complète de l'aisselle, on put, dans deux de ces cas, détecter d'autres ganglions lymphatiques dans l'aisselle, grâce à un compteur à scintillation directionnel. Les auteurs suggèrent que la technique décrite ou une de ses modifications pourrait être un moyen supplémentaire intéressant pour détecter les ganglions lymphatiques au cours de l'opération.

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A STUDY OF THE LYMPH DRAINAGE OF THE LOWER LIMB WITH THE USE OF COLLOIDAL RADIOGOLD (Au^{198})

by

K. A. Hultborn, L.-G. Larsson and *I. Ragnhult*

In malignant tumours of the soft tissues of the lower extremities, vulva, penis, and anal region, there is considerable diversity of opinion as to the best way of treating the regional lymph nodes. The approach must be based both on general clinical experience and on the anatomic knowledge of the lymph drainage. We propose to survey briefly the drainage from the lower extremities.

Anatomy. According to RAUBER-KOPSCH's Textbook of Anatomy (1922), lymph is drained from the lower extremities via one superficial and one deep lymphatic system. The superficial lymph vessels empty into the superficial inguinal nodes, from which, lymph vessels in turn run to the deep inguinal nodes. From the lateral surface of the foot and lower leg, a few superficial lymphatics are directed to the popliteal nodes. Deep lymph vessels communicate with these popliteal nodes and others with the anterior tibial node. The deep lymphatics run, either directly or via these nodes, to the deep inguinal nodes, the most cranial of which, Rosenmüller's gland, is situated immediately distal to the inguinal ligament or in the lacuna vasorum beneath it. Other deep lymph vessels from the muscles of the gluteal region and the adductor muscles of the thigh run into the pelvis, together with the gluteal and obturator vessels, and are conducted to lymph nodes along the course of internal and common iliac vessels. Lymph nodes along the external iliac vessels receive lymph vessels from the deep inguinal nodes. In CUNNINGHAM's Textbook of

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Anatomy (1951), it is stated that certain exceptions and peculiarities must be noted: (a) A few lymph vessels from the skin over the area of the short saphenous vein accompany that vessel into the popliteal glands; (b) at several points lymph vessels leave the superficial stream and are conducted along the blood vessels through the deep fascia to join the deep stream. TAYLOR and NATHANSON (1942), in describing the lymph nodes of the groin, included the external iliac nodes, because they complement the nodes of the femoral triangle and because they should be included in most dissections of the femoral area. The iliac nodes are closely grouped about the external iliac vessels. Their efferents, jointed by the hypogastric lymphatics, pass upward to the common iliac and periaortic chains of nodes. ROUVIÈRE (1932) described a communication between the superficial lymphatic system in the region of the gluteal fold and the common iliac lymph nodes.

Clinical aspects. BASSET (1912) described a technique which he had devised for radical groin dissection with concomitant excavation of iliac lymph nodes.

PACK and REKERS (1942), following an anatomic study of the lymph drainage, described the metastasis in melanosarcoma of the lower extremities, and planned the operative treatment with due regard to it. From ROUVIÈRE's investigations, they considered that some melanomas and sarcomas of the gluteal skin might metastasize directly to the common iliac lymph nodes without intervening regional-node involvement. They emphasized, further, that melanomas of the skin of the heel and lateral part of the foot metastasize to the popliteal nodes. Since lymph is drained from the popliteal to the deep inguinal nodes, the latter may be the site of metastases without involvement of the superficial inguinal nodes. In the opinion of PACK and REKERS, radical groin dissection together with dissection of the deep iliac lymph nodes should therefore be performed as a routine for all melanomas of the extremity, in some cases combined with removal also of the popliteal nodes. DASELER et al. (1948) and MENDELSOHN et al. (1949) described a somewhat different operative technique for radical groin dissection together with dissection of deep iliac nodes.

At Radiumhemmet and the Department of Surgery of Karolinska Sjukhuset, the treatment of regional lymph nodes is usually radiologic and surgical combined. Both the radiologic (teleradium according to Berven's technique) and the surgical treatment (lymph-node dissection according to HYBBINETTE and HELLSTRÖM) is directed against metastases in the groin and based on the assumption that lymph-node metastases in the iliac fossa do not occur in any major proportion of the cases.

To study the lymph drainage from the lower limb we have used radio-

active gold, Au^{198}, as red colloid and now present a preliminary report on the observations made in five experiments conducted so far.

A tracer dose of colloidal Au^{198} (0.09 to 2.5 mC) was injected into the lower limb, and by *in vivo* measurement with a directional scintillation counter the deposition of the radioisotope in the lymph nodes could be studied. The directional scintillation counter had a cylindric collimeter with a length of 10 cm, an aperture diameter of 1.2 cm and a lead thickness of 2.5 cm; the results of these measurements are illustrated in Figs. 1 to 5.

In order to obtain a more quantitative idea of the distribution, we also made measurements with a wide-angle scintillation counter over the site of the injection, the popliteal fossa and the inguinal-iliac region. The scintillation counter was adjusted to a distance of 27 cm from the skin over the respective regions and was shielded from the adjacent regions with a wide-angle conical lead collimator. The values were corrected for body background by measuring the region with the same geometry but covered with a thick lead shield. The resulting counting rates were expressed as percentages of the counting rates given by a standard solution of Au^{198}, which at the time of the injection had the same activity as the tracer dose injected. These values included, of course, major errors due to geometry and absorption, but gave a rough idea of the distribution of the isotope and the rate of uptake in the lymph-node regions. Table 1 gives an example of these measurements.

Table I

Distribution of the injected radiogold in Case 1 (correction for physical decay)

Time after injection	Site of Measurement: Place for injection in the calf	Popliteal fossa	Groin and iliac fossa
2 hours	91.6 per cent	1.1 per cent	5.3 per cent
4½ »	86.6 » »	1.9 » »	8.0 » »
24 »	83.8 » »	2.4 » »	11.8 » »
72 »	77.6 » »	3.0 » »	14.5 » »

In four cases, we studied the lymph drainage from the calf. The tracer dose was injected intracutaneously in Case 5, in the superficial subcutaneous tissue in Cases 2 and 4, and in the deep subcutaneous tissue in Case 1. In Case 3, the injection was given intracutaneously on the lateral surface of the thigh.

Case Reports

Case 1. 38-year-old man with carcinoma of the penis. A few small lymph nodes, not considered metastases, were palpated in the left groin. A tracer dose of colloidal radiogold was injected deeply in the subcutaneous tissue of the left calf. *In vivo* measure-

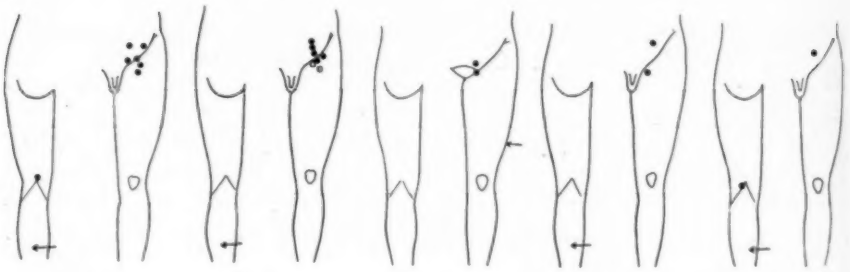

Fig. 1. Fig. 2. Fig. 3. Fig. 4. Fig. 5.

Figs. 1—5. Schematic figures illustrating the result of *in vivo* measurements with a directional scintillation counter after injection of colloid radiogold in the lower limb. The arrows mark the site of the injection. The black circles indicate spots with high counting rates, definitely representing lymph nodes with uptake of radiogold. The white rectangles show large palpated lymph nodes without demonstrable uptake.

ments with the directional counter revealed uptake of the isotope in lymph nodes in the popliteal fossa, the groin and the iliac fossa (Fig. 1).

Case 2. 51-year-old man with malignant lymphoma (lymphocytic-lymphoblastic lymphoma). No roentgen therapy had been given over the groin or pelvis. Several enlarged lymph nodes were palpated in both groins. On 12 March, 1954, a tracer dose of radiogold was injected into the superficial subcutaneous tissue of the left calf. *In vivo* measurements showed uptake in inguinal and iliac lymph nodes (Fig. 2). In some large superficial lymph nodes in the groin no uptake could, however, be demonstrated (marked with white rectangles in Fig. 2). On 15 March, a conglomeration of superficial and deep inguinal nodes was extirpated. Microscopy revealed a malignant lymphatic process, probably lymphoblastic (lymphocytic?) lymphoma. Radioautographs showed greatly varying uptake of the isotope in the lymph nodes, notably in areas with a more normal appearance (Fig. 6).

Case 3. 26-year-old female with a suspected malignant nevus on the lateral surface of the left thigh. A tracer dose of the radiocolloid was injected into the lateral surface of the left thigh at the junction of the middle and distal thirds. *In vivo* measurements revealed localized uptake both proximal and distal to the inguinal ligament, definitely in inguinal and iliac lymph nodes (Fig. 3).

Case 4. 75-year-old man with carcinoma of the rectum. In the left groin, a lymph node of the size of a cherry stone was palpated, clinically not suspected of malignancy. After injection of Au^{198} into the superficial subcutaneous tissue in the left calf uptake could be demonstrated *in vivo* in inguinal and iliacal lymph nodes (Fig. 4).

Case 5. 64-year-old man with carcinoma of the rectum. After intracutaneous injection of Au^{198} into the left calf uptake was demonstrated in popliteal and iliac lymph nodes (Fig. 5). No uptake was demonstrated in the lymph nodes in the groin.

In each case, an uptake of radiogold was thus demonstrated in lymph nodes proximal to the inguinal ligament; in two cases 7 cm above that ligament. By measurements with the directional scintillation counter in

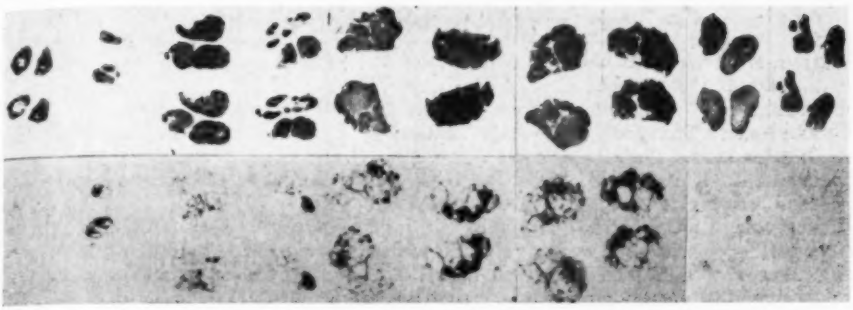

Fig. 6. Excised inguinal lymph nodes from Case 2 (lymphoblastic lymphoma), showing varying uptake of Au^{198} (stained section above, radioautographs below).

different planes against the skin the approximate depth of these lymph nodes could be determined and their position corresponded well with the external iliac lymph nodes. In one case, no uptake could be demonstrated in the inguinal lymph nodes, and, in a further case, uptake was only found in the most medial part of the inguinal lymph node region. In two cases, in which the calf was injected, an uptake was demonstrated in the popliteal lymph nodes; in one of these cases, the injection was given intracutaneously.

This preliminary investigation thus demonstrated *in vivo* the direct lymph drainage from different parts of the lower limb to the iliac lymph nodes. It seems probable that further studies of this type may increase our knowledge about the regional lymph drainage and also give valuable indications for the adequate treatment of cases of malignant tumours.

SUMMARY

By the use of colloidal radiogold, Au^{198}, the direct lymph drainage from different parts of the lower limb to the iliac lymph nodes was demonstrated *in vivo*. Five illustrative cases are presented.

ZUSAMMENFASSUNG

Mit Hilfe von kolloidalem radioaktivem Gold, Au 198, wurde die direkte Lymphdrainage von verschiedenen Teilen der unteren Extremität zu den iliacalen Lymphdrüsen *in vivo* demonstriert. Fünf illustrative Fälle werden präsentiert.

RÉSUMÉ

L'emploi de l'or colloïdal radioactif Au^{198} a permis de démontrer *in vivo* le drainage lymphatique direct de différentes parties du membre inférieur vers les ganglions lymphatiques iliaques. Présentation de cinq exemples.

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PIN-HOLE AUTORADIOGRAPHY[1]

by

Erik Odeblad

Pin-hole autoradiography has been used as a method of obtaining images of the distribution of radioactive isotopes in living organisms and other objects. Since there seems to be a lack of a general appreciation of certain properties and applications of the pin-hole camera, the author feels that it may be of interest to review the literature and report some of his own experiences in the present paper.

The principle of pin-hole autoradiography is simple. The object is placed in front of a screen or support provided with a hole, behind which an image is formed due to the straightline path of the radiation.

Theoretical considerations. Let us consider a pin-hole camera of the general arrangement as shown in Fig. 1. The pin-hole is placed at the distance a from a specimen of size A. The distance from the pin-hole to the image is b, the *depth* of the camera is $(a + b)$ and the size of the image is B. The *magnification*, M, is given by the equation

$$M = b/a = B/A \tag{1}$$

The *opening* on the camera is $2 \operatorname{arctg} \frac{A}{2a}$

If the diameter of the pin-hole is D, the area occupied by the pin-hole is $\pi D^2/4$. The area of a sphere of radius a is $4 \pi a^2$, and a fraction, Q, of the total emitted radiation enters through the pin-hole. We then have

$$Q = D^2/16\ a^2 \tag{2}$$

Q can be denoted the *geometrical efficiency* of the pin-hole camera.

[1] Being a revised part of a lecture given at the University of California, Berkeley and Oak Ridge Institute of Nuclear Studies, Tennessee, U. S. A.

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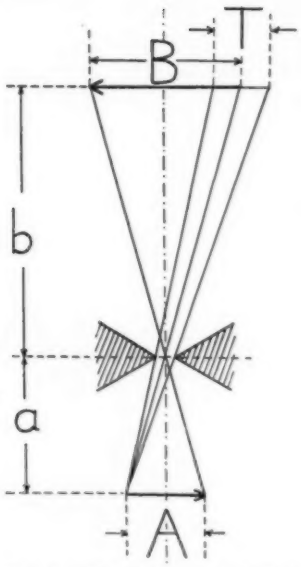

Fig. 1. Principles of pin-hole autoradiography. The specimen to be pictured is of size A and the image of size B. The pin-hole, of diameter D, is situated between the two shadowed cross sections of the pin-hole support. Other notations, see text.

Another important property of the pin-hole camera is the *resolution*, T. It is obtained from simple geometrical considerations and

$$T = D\ (a + b)\ /a = D\ (1 + M) \qquad (3)$$

However, the resolution in relation to the size of the image is more relevant for the applicability of the method and for the *relative resolution*, S, we may write,

$$S = T/M = D\ (1 + 1/M) \qquad (4)$$

Considering a point source, the area of the pin-hole shadow on the film increases with the square of $(a + b)$ when the depth is increased. The *intensity* of the exposure, I, is therefore

$$I = c_1/\ (a + b)^2 = c_2/\ (1 + M)^2 \qquad (5)$$

where c_1 and c_2 are arbitrary constants.

There are some aberrations of the pin-hole camera, one of which is the decrease in geometrical efficiency at oblique incidence due to the apparently less pin-hole and greater effective depth.

On the basis of these considerations, we may summarize the general properties of the pin-hole camera as follows. In decreasing the pin-hole diameter the resolution becomes better but the geometrical efficiency of the camera decreases with the square of the pin-hole diameter. The resolution relatively to the size of the image increases when the magnification is increased, and approaches a limiting value asymptomatically when the magnification is raised by increasing the depth of the camera. Finally, the exposure time increases with the square of the depth. A good pin-hole camera would therefore have small depth, small pin-hole, and small relation of a/b. However, the opening of the camera will increase and introduce parallactic distortion of the image if the specimen is thick, as well as aberrations.

The construction of the pin-hole camera. In planning the construction of a pin-hole camera and the performance of pin-hole autoradiography, it is important to consider the absorption of the type of radiation used. If the radiation is strongly absorbed in matter (as in the case of alpha rays), this implies that the source of radiation must be very thin. On

the other hand the construction is simplified because the pin-hole support does not need to be very thick to absorb the undesired radiation. Short range of the radiation also means that it is effectively absorbed in the photographic emulsion. The camera often has to be evacuated or placed in an evacuated chamber.

On the contrary, if the radiation is very penetrating as in the case of gamma rays of a few MeV, it has the advantage that thick specimens may be represented. In this case, the pin-hole support must be thick and the construction of the pin-hole is more difficult if undesired stray radiation is to be avoided. The radiation is absorbed very poorly in ordinary photographic emulsions, so that intensifiers of some kind have to be used. The camera usually needs no evacuation.

Many types of radiation (soft gamma rays, hard and soft beta rays) take up intermediate positions between these two extremes.

Pin-hole camera for alpha rays. The resolution of alpha particle autoradiography with apposition techniques may easily be better than 1 μ. No practical improvement of resolution seems possible with a pin-hole camera since the geometric efficiency for a pin-hole of the order of size of 1 μ will be about 10^{-10}. In addition, the careful construction of a pin-hole of this small size seems difficult. One field of use of the alpha ray pin-hole camera is the measurement of distribution of very active alpha sources. Such an application has been employed by BEAMER and MAXWELL (1946), MORRIS and LOCKENWITZ (1948) and ODEBLAD (1954), mainly for the control of distribution of RaE and RaF (Po^{210}). The camera may be evacuated in order to reduce the scattering of the alpha particles, but this is sometimes unnecessary. The source of radiation should be thinner than 10 mg/cm^2 otherwise considerable self-absorption of alpha rays will occur. If there is a mixture of two alpha emitters of varying range, this may be utilized in order to obtain a selective picture of the long-range isotope in an airfilled camera.

A discussion of pin-hole autoradiography with alpha rays is given by YAGODA (1949, p. 25—26), who states that for representing a Po^{210} source of 1 C/cm^2, using $D = 50$ μ and $a = b = 5$ cm, an exposure time of 43 sec. is required if 10^7 alphas per cm^2 are required to form an image (fine-grain emulsion). These statements are in agreement with the author's own experiences.

The support for the pin-hole of the author's camera is a thin lead foil for use in the case of pure (or nearly pure) alpha emitters.

Pin-hole camera for beta rays. The performance of pin-hole autoradiography of beta rays is strongly dependent on the energy of the beta particles. If weak beta rays are utilized, *e. g.* from Ni^{63}, C^{14}, P^{33} or S^{35}, half of the beta ray energy is absorbed in a few mg/cm^2. This

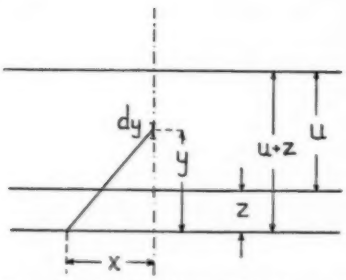

Fig. 2. Scintillating phosphor of thickness u on the distance z from the emulsion. The scintillating element dy exposes a point in the emulsion with the coordinates y and x.

implies that the source of radiation should be thin and that the energy absorption in the emulsion is quite sufficient if, for example, ordinary non-screen roentgen film is used. The camera should be evacuated.

If the energy of the beta rays is higher, *e. g.* if P^{32}, Cl^{36} etc. are used for pin-hole autoradiography, the thickness of the source is less critical and sources of several mm thickness can be tolerated. On the other hand the energy absorption in the film is small, amounting to only a few per cent of the total available energy, and in order to increase the efficiency a scintillating phosphor should be placed in front of or behind the film; such a phosphor may be vaseline, NaI(Tl) or commercial roentgen film intensifiers. The use of a phosphor implies, however, a reduction of resolution.

Consider a homogeneously scintillating phosphor of thickness u at the distance z from the emulsion. A small scintillating element dy at the distance y from the emulsion gives the exposure $C \cdot dy/(y^2 + x^2)$, see Fig. 2. The integrated exposure E_x is then

$$E_x = C \cdot \int_z^{u+z} dy/(y^2 + x^2) \tag{6}$$

which yields

$$E_x = C\ (1/x) \cdot [\text{arctg}\ (u + z)/x - \text{arctg}\ (z/x)] \tag{7}$$

and

$$E_o = C\ [1/z - 1/(u + z)] \tag{8}$$

The value of $2x$ for $E_x = {}^1/_2\ E_o$ is defined as the *screen resolution*. Considering a case in which $z = 0.2$ mm and $u = 2$ mm, we find that $2x$ is about 1 mm. Nothing can therefore be gained in total resolution by making the pin-hole considerably smaller than 1 mm in diameter.

The intensity of scintillations within the phosphor is not homogeneous but most intense nearest the pin-hole, due to geometric and absorption factors. The effect of this is that equations 6, 7, and 8, do not hold exactly and it is more favourable to place the scintillator behind than in front of the emulsion surface. Close contact between the emulsion and phosphor is essential, as seen by equation 8.

It is also important to match the phosphor scintillation spectrum and spectral emulsion sensitivity to each other. Some spectral data are

given in Table I. Nothing can be gained in resolution by using fine-grain film, but the sensitivity of the film may be increased if the grains are coarse.

Table I

Spectral data for the light emitted from scintillators and the sensitivity of photographic emulsions — collected from several sources in the literature, mainly from STAUB *(1953) and* JAMES *and* HIGGINS *(1948)*

A	B	C	D	E	F
Terphenyl	3,900	300			
NaI(Tl)	4,100	400			
Antracen	4,400	300	Unsensitized	4,500	250
$CaWO_4$	4,400	350			
$CdWO_4$	5,200	400	Panchromatic	5,200	900

A. Type of scintillator. B. Peak of emitted light in AU. C. Approximate half-width of emitted light in AU. D. Type of photographic emulsion. E. Peak of emulsion sensitivity in AU. F. Approximate half-width of emulsion sensitivity in AU.

Pin-hole autoradiography of beta emitters may, among other things, be used for the control of enclosed beta ray isotopes, the study of distribution of isotopes in small living animals, and the distribution of radioisotopes in beta ray applicators.

Pin-hole autoradiography of gamma rays. The weak interaction of gamma rays with matter implies a heavy construction of a pin-hole camera for gamma rays. A convenient construction is shown in Fig. 3. The two gamma ray cameras at the author's laboratory are of this type. The design has been given by COPELAND and BENJAMIN (1949), who constructed a camera with which they could obtain pictures of radium needles, having better resolution than apposition autoradiographs. The pin-hole had a conical inlet and outlet and a diameter of 0.1 mm. An autoradiograph of a 6 mg Ra needle required 48 to 72 hours exposure at a primary magnification of 4 ×. The distance to the object was about 12 cm. In order to overcome the weak interaction of gamma rays with the photographic film, these authors suggested the use of an image amplifier (Fluoricon amplifier) according to COLTMAN (1948).

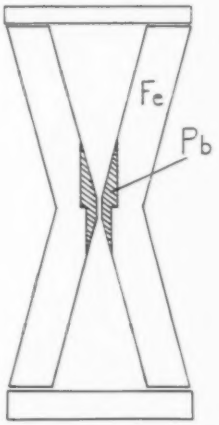

Fig. 3. Cross section showing the principal construction of the gamma ray pin-hole cameras used by the author.

Amplification by means of a phosphor was used by ANGER (1952) who utilized the scintillations produced in a NaI(Tl) crystal in order to increase the exposure of the film. This crystal was

Fig. 4. Print of a gamma ray pin-hole autoradiograph of a 23 mC Co^{60} applicator of primary magnification 1 : 1. Resolution about 4 mm. $a = b = 15$ cm, $D = 2$ mm. High brilliancy intensifier, Ilford X-ray double coated film. Exposure time 1 hr.

placed in front of the film and had a thickness of about 7.5 mm, the distance to the film being about 1 mm. With this arrangement the resolution, calculated from equations 7 and 8 is about 5 mm. With a pin-hole diameter of about 3 mm and $a = b =$ about 20 cm, an autoradiograph was obtained of a iodine-containing tumour (thyroid metastasis) of a patient who had received 100 mC I^{131}. The tumour contained about 20 mC. It had an apparent area of about 20 cm^2 as judged from the films (an activity of about 1 mC/cm^2). The time of exposure was 1 hour; the exposure was made in vivo. Kodak 103a-0 spectroscopic plate was used, slightly overdeveloped in D-19 developer.

The views presented above regarding the scintillating phosphor are applicable in general also to the gamma ray camera.

A pin-hole autoradiograph of a Co^{60} applicator is shown in Fig. 4.

Gamma ray autoradiography with a pin-hole camera seems at present to have more applications than alpha and beta ray autoradiography. Control of distribution in applicators, control of distribution of therapeutically administrated radioisotopes and in animal experimentation are some important fields.

As regards gamma ray autoradiography the main problem, especially for clinical applications, the proper method of image amplification, is not yet sufficiently elaborated.

General remarks. Pin-hole autoradiography is possible for alpha, beta and gamma rays from radioactive isotopes. The method has however considerable drawbacks, one of which is the low geometrical efficiency, which implies that only a very small part of all the particles or quanta emitted are utilized for the image formation. As long as good focussing methods are lacking for radiations from radioactive isotopes, it is necessary to utilize the pin-hole camera for certain applications, or alternatively, collimation methods, less good focussing methods, or scintillography.

At present the fields of application seem to be limited to the few examples given above and certain others. In these cases, however, the pin-hole camera is an important instrument in experimental and clinical work.

The other parts of this lecture (on focussing and collimation methods in autoradiography) and the author's applications of pin-hole autoradiography to specific problems will be published later.

Acknowledgement

The author takes the opportunity of thanking Stig Odeblad of Laxå, Sweden, who constructed the gamma ray cameras.

SUMMARY

The general properties of the pin-hole camera are described. Differences in construction and performance for extremely short-range and long-range radiations are discussed. The practical performance of alpha, beta and gamma autoradiography with a pin-hole camera are given and some examples of the applications mentioned.

ZUSAMMENFASSUNG

Die allgemeinen Eigenschaften der Lochkamera werden formuliert. Die verschiedenen Konstruktionsprobleme für Strahlen von sehr kurzer und sehr langer Reichweite werden diskutiert. Das praktische Ausführen von Alfa-, Beta- und Gamma-Autoradiographie mit der Lochkamera wird beschrieben und einige Beispiele werden gegeben.

RÉSUMÉ

L'auteur décrit les propriétés générales de la chambre trouée et discute les différences de construction de la chambre pour les radiations pénétrantes et pour les radiations non-pénétrantes. Il décrit la pratique de l'autoradiographie avec la chambre trouée en utilisant les rayons alpha, bêta et gamma et donne quelques exemples.

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THE SPECIFICATION OF ROENTGEN RAY OUTPUT AND QUALITY

by

R. F. Farr

In addition to stating the voltage and current rating of a roentgen therapy tube, manufacturers are now commonly stating an output "free in air" at a given half-value layer. In comparing the performances of roentgen machines of different makes it is important to consider how the reported output and quality of the radiation have been measured.

Table 1

Output and half-value layer of the beam from the same tube when measured in the factory and at the hospital

Filter	Hospital Measurements		Factory Measurements	
mm Cu.	Output r/min.	H. V. L. mm Cu.	Output r/min.	H. V. L. mm Cu.
0	85	1.8	90	2.1
0.5	66	2.0	74	2.5
1.0	56	2.4	61	3.0

Table 1 shows the outputs and qualities measured on a certain prototype apparatus, first at the factory and, subsequently, upon the identical apparatus, at this hospital. It was a matter of concern to both parties that the output and half-value layer were both higher at the factory than at the hospital. In both cases the apparatus was operated at the maximum rated tube voltage and current and with the added filters tabulated. The two dosemeters employed were compared and our figures have been adjusted to allow for the absorption of materials of low atomic number, such as a perspex monitor chamber, that were present during our measurements alone. At the factory, with no added filter, the tube gave an apparent half-value layer of 2.1 mm of copper and an output of 90 r/min. In this

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hospital about 0.6 mm of copper added filter is necessary to obtain a narrow-beam half-value layer of 2.1 mm of copper and the output is then about 63 r/min., or 30 per cent less.

Our explanation of this discrepancy illustrates some of the difficulties encountered in the comparison of outputs and qualities reported from different sources.

The *output* is frequently stated to have been measured, or a specification calls for a certain output, "*free in air*", at a given distance from the tube focus. The phrase quoted, which appears in some recommendations, is open to varying interpretation. Reasonably enough, it was taken at the factory to mean that the air between the tube and the measuring chamber should be free of all objects. Measurements were made with the applicator, applicator turntable, the shutter, etc., removed from the apparatus. The tube has a long, narrow extension anode of copper and a 45-degree target. The beam emerging from a close-fitting lead shield, 1.25 cm thick, had a half-angle of 25 degrees. We consider that the radiation scattered by the wide, irradiated air-column and, in view of its closeness to the focus, by the window of the copper extension anode itself, increased the apparent output, and we have tried to estimate by how much. The extension anode and the water jacket together had a window thickness of 1 mm copper. The inherent filtration further comprised low atomic number materials said to be equivalent to 0.3 mm copper.

We have measured the output in air at a point on the central ray, 50 cm from the focus, the beam being limited by a single lead diaphragm in the position normally occupied by the base of an applicator, 21.5 cm from the focal spot. Table 2 gives the relative output so measured with a series of different apertures in the diaphragm and with no added filter. The output in air increases with the area of the beam. The comparatively rapid rise at first is attributed to the increase, up to a maximum, of the amount of off-focus radiation received by the chamber as more and more

Table 2

Effect of the size of the beam upon the measured output in air

	Size of diaphragm placed 21 cm from focal spot	Relative dose rate in air	Effective size of beam in position of chamber	Effective target area seen by chamber
(1)	1 × 1.5 cm	81 r/min.	0.8 × 2.1 cm	1.4 × 2.0 cm
	2.1 cm dia.	92.5	3.7 cm dia.	3.1 cm dia.
(3)	4.1	95	8.9	6.3
	5.0	96.5	11.3	
	6.8	96.5	15.4	
	7.9	98	17.8	
(2)	13.5	100	33.0	
	(Factory	102)		

of the target plate is revealed to it. It then increases more slowly, due presumably to scattered radiation from the larger area of copper exposed and from the wider irradiated air-column. Our own measurements given in Table 1 were made with a small field, approximately of the size of (3). The widest beam available to us now is limited by the applicator turntable to a half-angle of 25 degrees and its use increases the output some 5 per cent. The use of the very wide field that was possible, and in fact made, at the factory will, it is thought, have enhanced the output even further.

The conditions under which the true *half-value layer* should be measured are generally agreed. However, textbooks and sources of a comparable standard do not always state them explicitly. Explicit instructions for the measurement of half-value layer are given in only one (JOHNS, 1953) of 11 textbooks and similar works, in English, examined. Measurement of half-value layer was made at the factory, again reasonably enough, under the same wide-beam conditions which had been employed for the measurement of output. The absorbers were placed close to the extension anode and the beam had a half-angle of 25 degrees, conditions which lead to an over-estimate of the half-value layer.

Our own measurements were made with a narrow beam. A lead diaphragm, a rectangle, approximately 1.5×1 cm, was placed 21.5 cm from the focal spot and the chamber was placed a further 30 cm away. The cross-section of the beam, exclusive of penumbra, at the chamber position was 2.1×0.8 cm and it just covered the chamber. Every point of the chamber could thus see the whole of the focal area, which was approximately 1.2 cm in diameter.

On a second insert we have studied the effect of the conditions of measurement upon the value obtained for the half-value layer. In the first place, we have measured the half-value layer (1) under the narrow-beam conditions just described and (2) with a wide beam, limited only by the applicator turntable to a half-angle of 17.5 degrees. Both measurements were made with the absorber and the chamber in the positions specified above. The apparent half-value layer increases with the area of the beam employed, viz.

(1) Narrow-beam half-value layer 1.80 ± 0.02 mm copper
(2) Wide-beam half-value layer 1.91 ± 0.02 mm copper

As well as the effect of the width of the beam upon the measured half-value layer, that of the focus—absorber and of the absorber—chamber distance must be considered. This has been investigated with an unnecessarily-wide beam, limited by a 4 cm diameter diaphragm placed in the applicator holder, 21.5 cm from the focus. When the absorber—focus distance is constant (21.5 cm) the half-value layer increases as the absorb-

er—chamber distance is decreased (Table 3). Similarly, when the chamber—absorber distance is constant (30 cm) the half-value layer increases as the absorber—focus distance is decreased (Table 4). The number of positions in which the absorber could be placed, within the tube housing, was limited. Position (a) refers to the absorbers placed in the filter carrier and position (b), in the applicator holder.

Table 3

Effect of absorber—chamber distance upon the measured half-value layer

Measured H.V.L. At 300 kVp, as against 265 kVp in Tables 1 & 2	Absorber—chamber distance
2.30 ± 0.02 mm copper .	2.5 cm
2.12	5
2.06	10
1.99	20
1.97	30..... (b)
1.96	60

Table 4

Effect of focus—absorber distance upon the measured half-value layer

Measured H.V.L. At 300 kVp, as against 265 kVp in Tables 1 & 2	Focus—absorber distance
2.06 ± 0.02 mm copper ..	10 cm ..... (a)
1.99	15
1.97	21.5 ..... (b)
1.97	31.5

It is clear that the half-value layer obtained in the factory (Table 1) was a reasonable value in view of the measuring conditions used.

Conditions under which output and half-value layer should be specified

The differences detailed above are, individually, small. It is possible, however, that divergences in the half-value layer produced by different techniques of measurement may lead in practice to some difficulty in the exchange of depth-dose data. For example, we had earlier found (Farr 1954), on another make of apparatus, that with zero and 0.5 mm of copper added filter, the half-value layers measured with a narrow beam and good geometry were 0.5 and 1.25 mm of copper. Measured with an open field (half-angle 17.5 degrees) by placing the additional absorbers in the filter carrier, they were 0.7 and 1.5 mm respectively.

When taken together, as is customary in stating an in-air output at a given quality, there is a significant total effect, as we have seen. Conditions under which the half-value layer and the output "free in air" should

be measured might well be laid down (FARR 1954). In comparing different makes of set it would help if such standard conditions were agreed and such guidance would, no doubt, be welcomed by manufacturers.

The question of *half-value layer* may be thought to present no difficulty. It is agreed that it should be measured with such a narrow beam and with the chamber and absorber so disposed that the former scatters little radiation into the latter. In fact, there is a considerable variation of practice in the experimental arrangement that is used. We have seen the thimble chamber placed very close to the absorber and we have also seen the absorber placed in the filter carrier, both of which arrangements are to be deprecated.

It is possible to determine the half-value layer uniquely for zero area of the beam if the dependence upon the area of the beam of the scattered radiation is known, *e. g.*, the formulae of TARRANT (1932) for once-scattered radiation. What is wanted for practical purposes, however, is an explicit statement of conditions (beam-width and focus—absorber—chamber distances) under which the true half-value layer may be determined to a sufficient approximation. The tables just presented, while by no means exhaustive, suggest that if the chamber is 50 cm from the focus and the absorbers are placed 20 to 30 cm from either, the measured half-value layer will for practical purposes be the true one. This condition generally allows the diaphragm and absorbers to be placed conveniently in the applicator holder. It is suggested that the beam, while being no wider than is necessary, should be sufficiently wide that every point on the chamber sees the whole of the focal spot.

With this arrangement, some of the off-focus radiation will also reach the chamber. In so far as this radiation arises from primary electrons, which have rebounded from the target with little loss of energy or, as in this extension anode, from primary electrons travelling outside the main stream, the off-focus radiation may be expected to have much the same quality as the radiation from the focal spot. In so far as this radiation arises from secondary electrons of lower energy ejected from the target or is radiation scattered by surrounding oil (not present in our example), collimating diaphragms and elsewhere, it may be softer than the radiation from the focal spot. In general, the inclusion of off-focus radiation can, if anything, only decrease the half-value layer. If only one diaphragm is to be used to collimate the beam the inclusion of some off-focus radiation represents a reasonable compromise. The use of more than one diaphragm allows radiation from the focus alone to be measured.

If the focal spot is not stable it may not be possible to measure the half-value layer with a narrow beam. On one insert with an extension anode there was random movement, accompanied by a change of shape, of the focal spot, which may have been caused by defocussing of the

electron stream within the extension anode due to the presence of gas. As a result, at one stage the thimble chamber used in the arrangement described above for the measurement of half-value layer, which could only "see" an area of the target roughly equal to the nominal focal spot, measured a dose rate which showed sudden variations of some 10 per cent overall. These could not be eliminated by simultaneously measuring the dose rates on either side of the collimating diaphragm (or their ratio, KEMP 1954). It was due to movement of the focal spot perpendicular to the central ray, determined fluoroscopically to be about 2 mm. When the focal spot, defining diaphragm and thimble chamber are, as in this case, of comparable size, such movement affects the chamber reading markedly. The tube was electrically stable, the tube current and voltage meters were quite steady and it could from that point of view be satisfactorily employed, even though the vacuum was relatively poor. Although measurements of dose made over a minute were reasonably constant it was not possible to measure the half-value layer.

The standardisation of *output* measurements is also open to discussion. The beam should, of course, be wide enough for the chamber as a whole to see the whole of the focal spot. Indeed, it should be somewhat wider since the off-focus radiation, which is an appreciable part of the whole, reaches the centre at least of the usual fields and must therefore be included in a comparison of output. BRADSHAW (1953) has shown that, in the case of a particular oil-immersed tube, it may amount to 10 per cent of the total and our figure (Table 2) is not dissimilar. In the latter case the output may be increased by slightly defocussing the electron stream down the extension anode, presumably causing an increase in the amount of off-focus radiation and it also depends upon the area of the target disc. While it contributes to the "output" of the machine, the off-focus radiation is to be avoided as far as possible, since it is only gradually cut-off at the edges of a field and, to an extent depending on the design of the applicator, may contribute to the curvature of the isodose curves there.

The field width should therefore be larger than that used for quality measurements, it should be large enough for the chamber to see the whole of the target plate and, because of the dependence of output upon the beam width, it should be standardised. The use of an actual applicator suggests itself as a convenient way of fixing the distance and the size of the field. Outputs of different machines might well be compared through their outputs in air on a 10 cm circular applicator at 50 cm focus-distance. Such figures, however, are not a measure of the performance of the tube alone, but also of the design of the applicator. If this has a closed end it will absorb radiation to an extent depending upon its thickness, and secondary radiation from the end and from the walls, if these are irradiated, will contribute to the output to an extent depending

upon the field size. For example, the output of a 5 cm circle may be 9 per cent less, and that of a 20 cm circle may be 9 per cent more than that of a 10 cm circle.

It is further possible, it may be supposed, by a "poor" design of applicator, to enhance its apparent output by several per cent. BRADSHAW (1953) has shown that, on a particular applicator, complete irradiation of the walls could increase the output by 6 per cent (while leaving unaffected the dose rate at a depth of 10 cm). Accordingly the output should be measured sufficiently far from the applicator face for this secondary radiation to be avoided, and a correction made by the inverse-square law to obtain that at the required focus-distance. Table 5 suggests that it would be appropriate to measure the output in air at 20.7 cm from the end of a 50 cm applicator and to multiply the result by two.

Table 5

Effect of the applicator (10 cm diameter circle at 50 cm focus-distance) upon the dose rate measured in air

Distance of chamber from applicator face	Measured dose rate in air	Dose rate in air corrected by inverse square law to applicator face
0.5 cm.....	88	89.5
0.8	86	88.5
2.25	79	86.5
6.3	66	84.0
10.7	55.5	83.5
15.5	46.5	80.0
20.5	40	79.5
29.5	31	78.5

If an applicator is used for the measurement of output it should not also be used to collimate the beam for the measurement of half-value layer, when the only available position for the absorber is in the filter carrier, which is generally too close to the focus. On the tube of our example, the apparent half-value layer measured in this way with a 10 cm diameter circular applicator was 1.85 mm of copper, intermediate between the narrow-beam and wide-beam values. JOHNS (1953) suggests that the beam should be collimated by a small applicator and the absorbers placed at its end, with the thimble chamber a suitable distance away. Then the half-value layer of the radiation leaving the applicator rather than that leaving the tube is measured. If central axis data referring to open-ended applicators is adapted to the use of closed-ended ones (by counting the applicator end as an equivalent amount of tissue (JOHNS 1952)), however, the appropriate half-value layer is the second, and not the first, which may be influenced by the applicator end.

Agreement on the measurement of half-value layer is perhaps of wider

importance than agreement on the measurement of output in air, inasmuch as the former is important in the comparison of depth doses, the latter only in the comparison of the performance of different machines.

SUMMARY

A discrepancy of 30 per cent in the output of a certain roentgen-ray tube at a given half-value layer when measured at the factory and at the hospital has led to an examination of the effect of beam width and of the influence of the applicator upon the output in air and of the effect of beam width and of the focus—absorber—chamber distances upon the measured half-value layer. Conditions under which the output and quality should be measured in the comparison of different tubes might well be laid down. The half-value layer should be measured with a thimble chamber placed not less than 50 cm from the focus, the absorbers placed 20 to 30 cm from either, and the beam width limited to just cover the chamber, free of penumbra. Some common experimental arrangements are criticised. The output "free in air" may be measured 20.7 cm from the end of a 10 cm diameter circular applicator at 50 cm focus distance and the result multiplied by 2 to obtain the effective value at 50 cm focus-distance.

ZUSAMMENFASSUNG

Ausbeuteabweichungen von 30 % einer gewissen Röntgenröhre bei einer gegebenen Halbwertschicht zwischen Messungen in der Fabrik und im Krankenhaus haben zu einer Untersuchung der Wirkung der Strahlenbreite und des Einflusses des Applikators auf die Ausbeute in Luft und zur Prüfung der Wirkung der Strahlenbreite und der Fokus—Absorptionskörper—Kammerabstände auf die gemessene Halbwertschicht geführt. Die Bedingungen, unter denen die Ausbeute und die Strahlenqualität beim Vergleich verschiedener Röhren gemessen werden sollen, müssen gut fixiert werden. Die Halbwertschicht sollte mit einer Fingerhutkammer gemessen werden, welche mindestens 50 cm vom Fokus entfernt aufgestellt ist; die Absorptionskörper sollen 20—30 cm von beiden entfernt und die Strahlenbreite so begrenzt sein, dass sie gerade die Kammer — ohne Penumbra — deckt. Einige gebräuchliche experimentelle Anordnungen werden kritisiert. Die Ausbeute in Luft sollte bei 20.7 cm Abstand vom Ende eines runden Applikators mit 10 cm Durchmesser bei einem Fokusabstand von 50 cm gemessen und das Ergebnis mit 2 multipliziert werden, um den effektiven Wert bei 50 cm Fokusabstand zu erhalten.

RÉSUMÉ

Une différence de 30 pour cent dans le débit d'un certain tube à rayons roentgen, pour une couche de demi-absorption donnée, suivant que la mesure était faite à l'usine ou à l'hôpital, a conduit à examiner l'effet de la largeur du faisceau de rayons et l'influence du localisateur sur le débit dans l'air, et l'effet de la largeur du faisceau et des distances foyer—couche absorbante—chambre sur la couche de demi-absorption mesurée. Les conditions dans lesquelles on devrait mesurer le débit et la qualité du rayonnement pour comparer différents tubes devraient être définies.

La couche de demi-absorption devrait être mesurée avec une chambre en dé à coudre placée à au moins 50 cm du foyer, les couches absorbantes éloignées de 20 à 30 cm du foyer et de la chambre, et la largeur du faisceau devrait être réduite de façon à couvrir juste la chambre, sans pénombre. L'auteur critique certains dispositifs expérimentaux

usuels. Le débit «dans l'air» peut être mesuré à 20.7 cm de l'extrémité d'un localisateur circulaire de 10 cm de diamètre donnant une distance foyer de 50 cm et le résultat, multiplié par 2, fournit la valeur effective à une distance foyer de 50 cm.

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EFFECTS OF COMBINED WHOLE BODY ROENTGEN IRRADIATION AND HIGH EXPLOSIVE BLAST INJURY IN MICE

by

Carl-Johan Clemedson and *Arne Nelson*

Introduction

It is a well-known fact that an atomic bomb explosion will, in addition to the production of conventional mechanical injuries and thermal burns, also endanger life by its radiologic effects. It is calculated that after an attack on a modernly built city, about 70 per cent of the survivors will suffer traumatic injuries, 65 per cent thermal burns and 15—35 per cent radiation lesions. A considerable number of the victims will suffer from two or all three types of injuries simultaneously.

As such a combination of different types of injuries must always be taken into account, it is surprising to find how little notice has been paid to combined injuries in the considerable literature now existing on atomic bomb effects. There is no doubt, however, that the combination of the two or three types of injuries will prove a serious problem as regards treatment and prognosis, and that it will greatly increase the death rate.

Only some few papers dealing with experiments have hitherto been published on this matter and have chiefly been concerned with the combination of thermal burns with radiation injury. Thus, BROOKS et coll. (1951, 1952) have shown that if dogs with a 20 per cent standardized second degree burn were, in addition, given 100 r of roentgen radiation, the death rate was increased from 12 per cent to 75 per cent. Even a roentgen dose as low as 25 r raised the death rate to 20 per cent. The considerable increase in the death rate in the combined injury group was presumed to be due to infection from β-hemolytic streptococci, and this was supported by the fact that if large doses of penicillin were administered, the mortality was reduced from 75 per cent to 14 per cent.

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Similar results were obtained by BAXTER et coll. (1953) in swine. If pigs exposed to a non-lethal 10 to 15 per cent flash burn were irradiated with 400 r the mortality showed an increase from the 20 per cent radiation mortality to 90 per cent. In another group of animals given exactly the same exposure but treated daily with 500 mg streptomycin, no increased lethality was obtained, but the mortality rate remained at 20 per cent.

Furthermore, it may be mentioned, that PARR et coll. (1952) have found that mice with combined injuries succumbed more rapidly than animals receiving roentgen irradiation only. ALPEN and SHELINE (1953) have studied in rats the combined effects of roentgen radiation and burns produced by dipping in hot water. A 31 to 35 per cent degree burn produced a death rate of 50, 65 and 100 per cent when combined with a roentgen dose of 0, 100 and 250 r, respectively. A 16 to 20 per cent degree burn, otherwise not lethal, will in combination with 500 r cause a mortality of not less than 75 per cent. Finally, DAVIS et coll. (1953) have studied the effects of high intensity radiant energy thermal burns and total body roentgen irradiation on the blood coagulation mechanism in rats. They were able to show that the thrombocytopenia and defective coagulation mechanism failed to account for the increased death rate in the 'combined injury' animals.

POHLE and co-workers (1949) found no deleterious effects of local roentgen irradiation on wound healing with doses up to 700 r, a result also supported by GUSTAFSON and CEBUL (1953). With larger doses (2,000 r), however, a certain delay was observed in the healing of wounds (LAWRENCE et coll. 1953, AEC 1954). SPITTLER et al. (1954) have studied the effects of whole body irradiation on the healing of fractures in rats. After having been exposed to doses ranging from 300 to 900 r the left femur of the animals was deliberately fractured. It was found that the whole body roentgen irradiation influenced and changed the normal development of cartilage and ossifying osteoid tissue, thus delaying the healing of the fracture.

As far as the combination of blast injury and irradiation is concerned, the only investigation seems to be that made by CASSEN and KISTLER (1953). They studied the degree of acute pulmonary edema produced by blast in radiation-weakened mice. A considerably higher degree of edema was encountered in animals exposed to mid-lethal whole body roentgen irradiation than in the case of non-irradiated controls subjected to blast.

With regard to the presumed occurrence of blast and irradiation injuries in the event of future atomic warfare, it seemed to be of considerable interest to study the effects of a combination of these two types of injuries.

Methods and Material

Four hundred and eighty white male mice of pure breed and weighing about 20 g each were used for this study. They were grouped in tens and exposed to roentgen irradiation in doses varying between 25 and 600 r. The data concerning the irradiation were: 145 kV, 6 mA, 1 mm Al and F. T. D. 38 cm. The dose rate was 76 r per min. The mice were kept in a special plastic holder during the irradiation.

Within a few hours after the irradiation the animals were exposed to a high explosive blast in a detonation chamber constructed especially for physiologic blast injury research (CLEMEDSON 1949, CLEMEDSON and CRIBORN 1954). All ten animals in the same group were exposed to the same explosion. Three different weights of explosive charges were used, *viz.* an electric blasting cap, a blasting cap and 0.5 g PETN (pentaerythrite tetranitrate) and a blasting cap and 1.0 g PETN, the lung injuries inflicted being judged as slight, moderate, and severe, respectively.

All the mice were weighed 3 times a week and the number of survivals noted every morning. The observation period was 30 days. The experiments were performed in three series. The conditions are tabulated in Table 1.

Table 1

Experimental Conditions

Test 1			Test 2			Test 3		
Group	Irradiation dose in r	Max. blast pressure kgf/cm²	Group	Irradiation dose in r	Max. blast pressure kgf/cm²	Group	Irradiation dose in r	Max. blast pressure kgf/cm²
I A	—	—	I A	—	—	I A	—	—
I B	—	3.7	I B	—	3.6	I B	—	4.2
I C	—	5.5	I C	—	5.4	I C	—	5.2
I D	—	6.6	I D	—	7.0	I D	—	6.5
II A	25	—	II A	50	—	II A	400	—
II B	25	3.7	II B	50	4.2	II B	400	4.1
II C	25	5.7	II C	50	5.4	II C	400	5.2
II D	25	6.6	II D	50	6.5	II D	400	6.7
III A	100	—	III A	200	—	III A	500	—
III B	100	4.7	III B	200	3.6	III B	500	3.8
III C	100	5.8	III C	200	5.5	III C	500	5.6
III D	100	6.5	III D	200	6.9	III D	500	6.5
IV A	300	—	IV A	400	—	IV A	600	—
IV B	300	3.8	IV B	400	3.8	IV B	600	3.8
IV C	300	6.1	IV C	400	5.7	IV C	600	5.6
IV D	300	6.8	IV D	400	6.7	IV D	600	7.1

The corresponding group symbols will be found in the figures.

Results

First test: Figs. 1 and 2 show the results of the first test. From the curves of average body weights, as well as those of survivals, it will be seen that there is no significant difference either between the exposed groups or between the exposed groups and the controls. In some of the groups irradiated, however, the increase of the average body weight appears later.

From Fig. 2 it is evident that the deaths in this test were due to blast injury and in no way to the combined effect of radiation and blast.

Second test: Fig. 3 shows the curves of the average body weights grouped in relation to the radiation dose. In all the 4 groups the curves follow each other relatively well, and in the non-irradiated and 50 r groups there is no significant deviation. In the 200 r groups the curves deviate more from each other at the end of the observation period than in Groups I and II, while the curve of Group III D ends above the other curves in the 200 r groups. In the 400 r groups there is a greater divergence at the end of the observation period than in the former groups, and in this case, too, the D curve is above the others. From Fig. 4 it is evident that there is no significant difference between the groups in the number of survivals, which can be interpreted as being caused by the influence of irradiation or by the combination of irradiation and blast. A relatively great number of deaths, however, take place the first day after the exposure, especially in the groups exposed to the highest blast pressures. The drop in the body weight curves on about the sixteenth day was due to an interruption in the feeding of the animals, beyond our control, and is of no importance in this connection.

In Figs. 5 and 6 the groups are rearranged with regard to the blast pressure. Fig. 5 shows that the average weight curves of Groups I to III follow each other rather closely in all cases, even if sometimes the weight increase at the beginning of the curves in Group III (200 r) appears later. All the curves in Group IV are below the others (I to III), but the distance between the curves in the former group and the others decreases unexpectedly with increasing blast pressure. From Fig. 6 it is obvious that the number of deaths is only correlated with the blast pressure.

Third test: In the third test the radiation doses were increased to a maximum of 600 r which is just about the $LD_{50\ 30}$ for mice.

From Fig. 7 it will be seen that the weight curves in the non-irradiated group diverge more than is the case in the non-irradiated groups in the first and second tests. In these, however, the conformity was so good that the deviation in the third test may be regarded as of no importance in the present investigation.

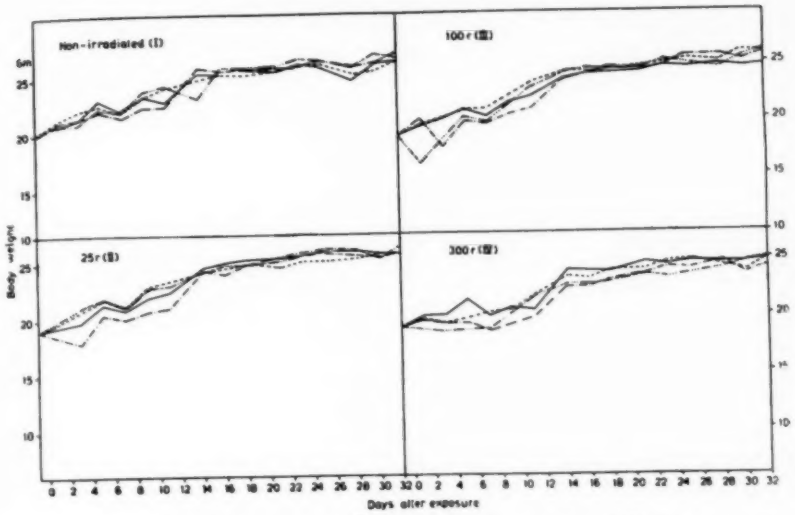

Fig. 1. First test. Average body weight. (See also Table 1.)
Group A ———, B - - - - -, C —·—·—, D — ··· —.

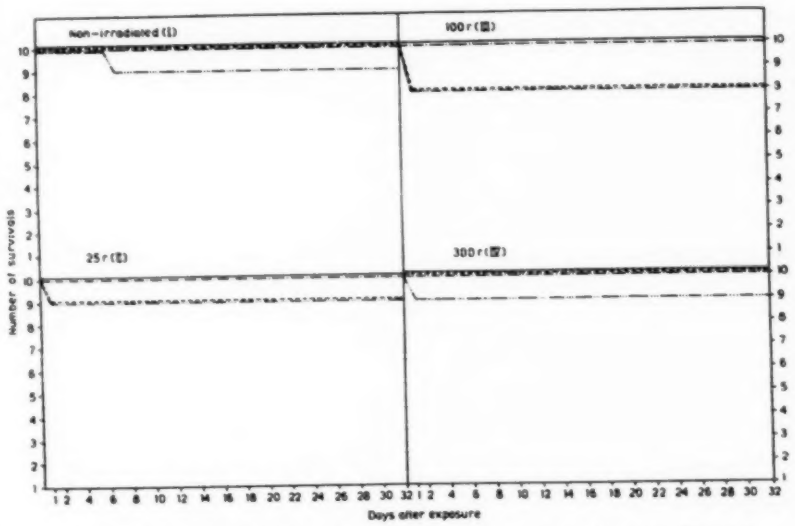

Fig. 2. First test. Number of survivals. (Group symbols as in Fig. 1.)

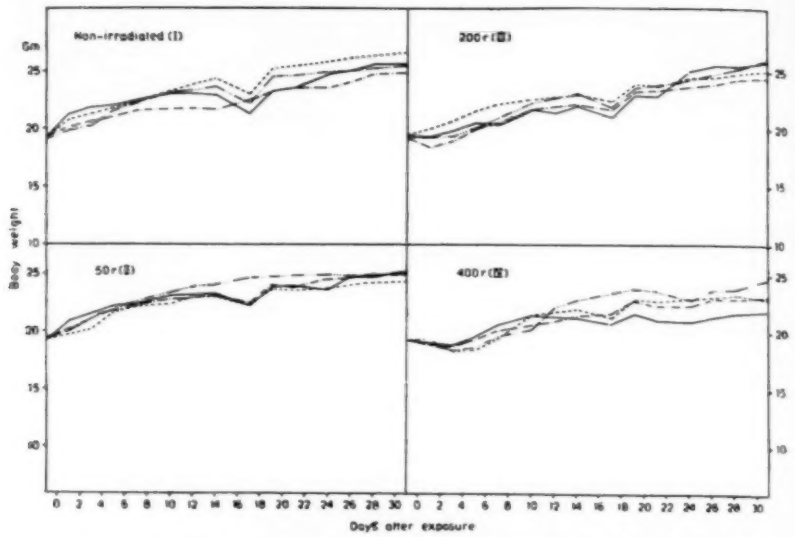

Fig. 3. Second test. Average body weight. Groups arranged with regard to radiation dose. (Group symbols as in Fig. 1.)

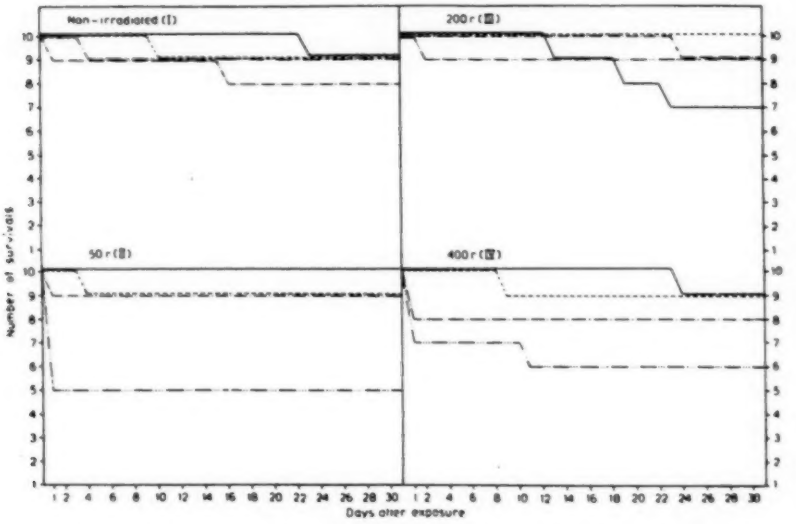

Fig. 4. Second test. Number of survivals. Groups arranged with regard to radiation dose. (Group symbols as in Fig. 1.)

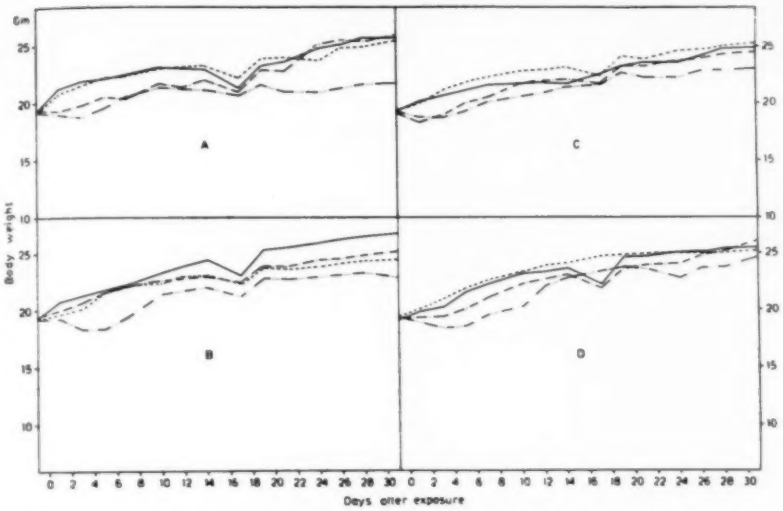

Fig. 5. Second test. Average body weight. Groups arranged with regard to blast pressure.
Group I ———, II - - - - -, III —·—·—, IV —···—.

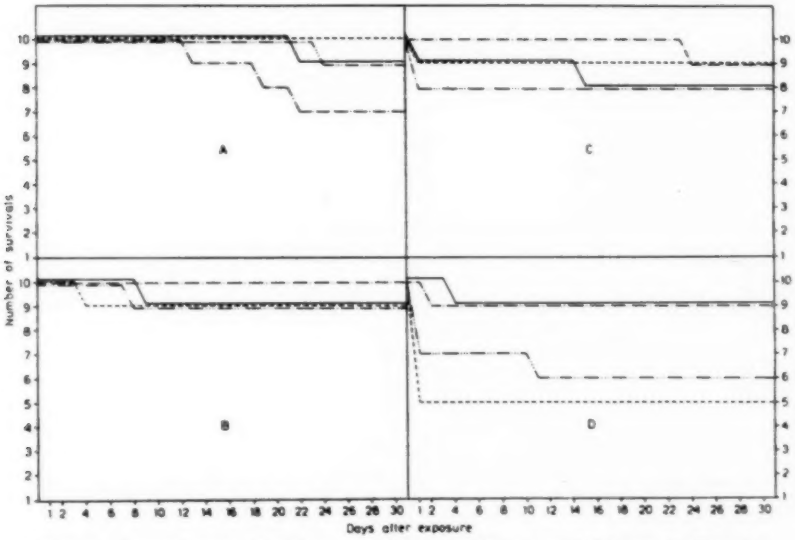

Fig. 6. Second test. Number of survivals. (Group symbols as in Fig. 5.)

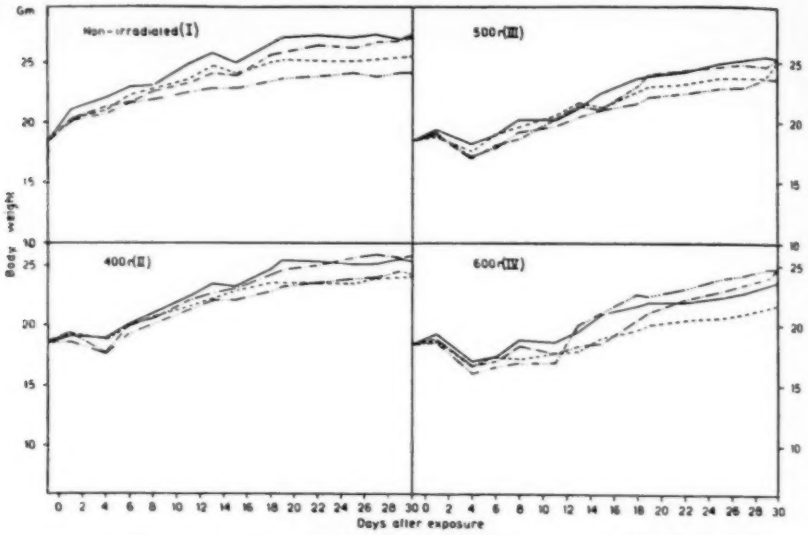

Fig. 7. Third test. Average body weight. Groups arranged with regard to radiation dose. (Group symbols as in Fig. 1.)

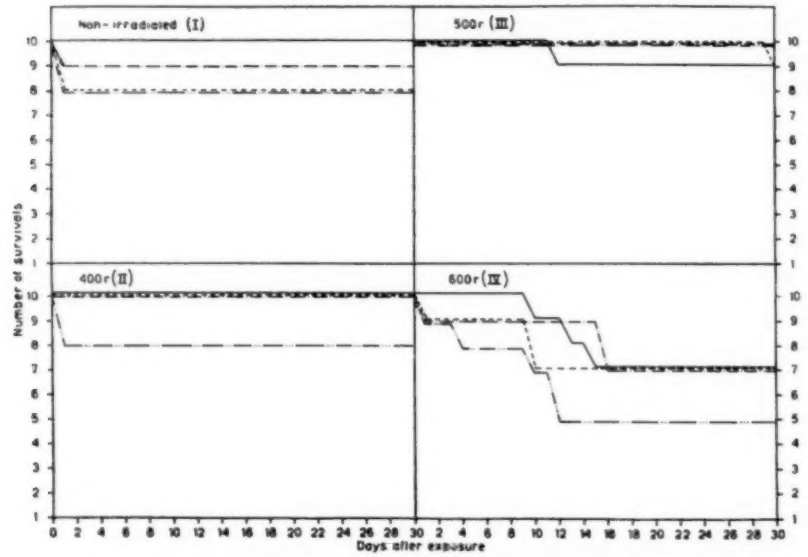

Fig. 8. Third test. Number of survivals. Groups arranged with regard to radiation dose. (Group symbols as in Fig. 1.)

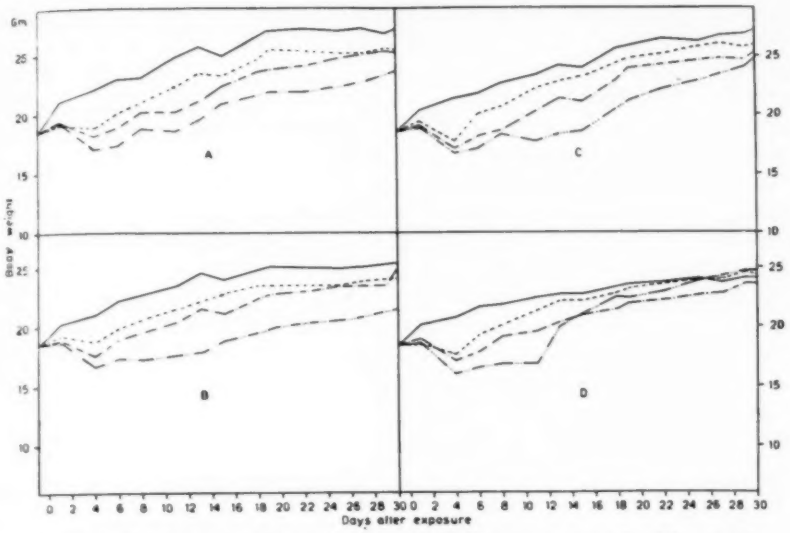

Fig. 9. Third test. Average body weight. Groups arranged with regard to blast pressure. (Group symbols as in Fig. 5.)

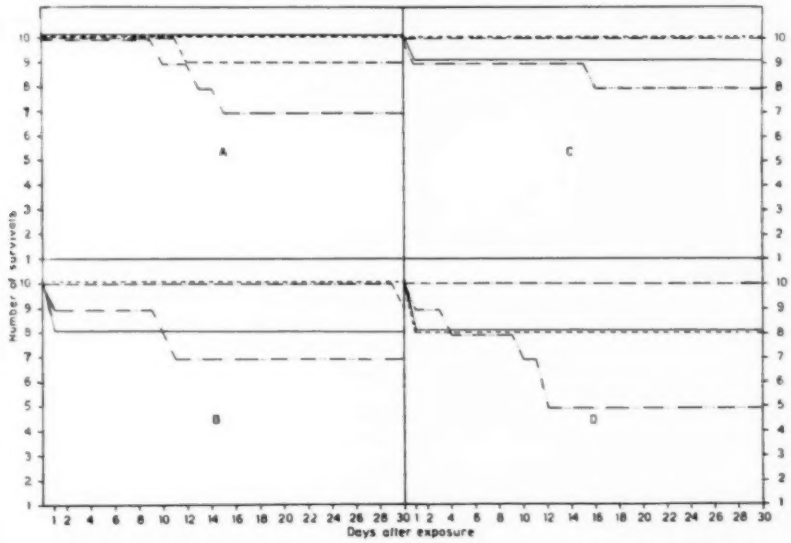

Fig. 10. Third test. Number of survivals. Groups arranged with regard to blast pressure. (Group symbols as in Fig. 5.)

A comparison between the irradiated groups shows that the average body weights usually decrease with increasing doses.

Within the irradiated groups there is no significant deviation between the individual curves. It is, however, remarkable that the IV D curve in Fig. 7 in the latter part of the observation period is above the other in this group, as is the case in the second test.

The number of survivals is shown in Fig. 8. All the deaths in the non-irradiated and the 400 r group occurred on the first day which must have been caused by the blast. The two late deaths in the 500 r group cannot be solely due to the blast effect.

In the 600 r group there are in addition to the few early blast deaths a considerable number which occurred between the 9th and 16th days.

In Figs. 9 and 10 the groups are rearranged in relation to the blast pressure, in the same way as in Figs. 5 and 6. The general course of the curves in Figs. 9 and 5 is the same. The unexpected increase in the IV D curve is probably due to the fact that it was the most vital animals that survived.

It will be seen from Fig. 10 that the number of deaths is correlated with the radiation dose and that the number of deaths in the group exposed to the highest blast pressure is higher than in those exposed to lower pressure. This is the only fact in this investigation indicating an effect of the combination of blast and radiation injury.

Some of the mice killed by the blast were examined by autopsy with special regard to lung injuries. The findings verified the statement that the highest blast pressure produced severe pulmonary injury.

Discussion

From earlier investigations it is obvious that the combination of burns with a radiation injury will give a worse prognosis than may be expected from a single injury. According to BROOKS et coll., BAXTER and others this effect is supposed to be caused by a blend infection.

A similar effect might be expected to appear after the combination of blast and radiation injuries. The present investigation on mice, however, has shown that this combination does not significantly change the average body weight or number of survivals in comparison with the controls, except in the group representing the combination of 600 r and the highest blast pressure. It is remarkable that if the average body weight groups are arranged according to the radiation doses, the curves representing the highest blast pressures are practically always at the top. If these groups, however, are arranged with regard to the blast pressure, the greatest radiation dose curves are below the others. It is evident that this depression in body weight is due to radiation injury.

It is remarkable that the highest blast pressures do not retard the weight increase or increase the number of deaths as might be expected. Instead, there is an accelerated increase in weight, indicating an improved resistance contrary to what might be expected from the considerable susceptibility to pulmonary infections, especially lung abscesses, in mice (JAFFÉ, 1931).

Acknowledgement

The irradiations were performed at the Institute of Radiophysics, Stockholm, for which we wish to express our thanks to Prof. R. SIEVERT and Dr. A. FORSSBERG.

SUMMARY

Groups of mice were exposed both to roentgen irradiation and high explosive blast. With the body weight curves and number of survivals as a criterion of the effect, no significant increase of the effect of the combination of the two exposures as compared with the influence of blast or irradiation alone could be observed, except in the group exposed to the highest blast pressure and radiation dose.

Contrary to what could be expected in some of the irradiated groups exposed to the highest blast pressures, an accelerated increase in body weight was observed after about two weeks.

ZUSAMMENFASSUNG

Gruppen von Mäusen sind sowohl Röntgenbestrahlungen als auch hochexplosiven Sprengungen ausgesetzt worden. Mit den Gewichtskurven und der Anzahl der Überlebenden als Kriterium der Wirkung konnte kein signifikatives Ansteigen der Wirkung der Kombination der beiden Exponierungen im Vergleich zum Einfluss von Explosion oder Bestrahlung für sich beobachtet werden. Eine Ausnahme bildete die Gruppe, die dem höchsten Explosionsdruck und den höchsten Strahlendosen ausgesetzt worden war.

Entgegen aller Erwartung wurde in einigen der bestrahlten und mit den höchsten Explosionsdrucken exponierten Gruppen nach etwa 2 Wochen eine beschleunigte Zunahme des Körpergewichtes beobachtet.

RÉSUMÉ

Des groupes de souris ont été exposés à la fois à une irradiation roentgen et à un violent souffle d'explosion. Les courbes de poids corporel et le nombre des survies ont servi à en juger l'effet et n'ont pas permis d'observer d'augmentation notable de l'effet de cette association par rapport à l'influence du souffle ou de l'irradiation isolés, sauf dans le groupe exposé à la pression de souffle et à l'irradiation les plus fortes.

Contrairement à toute attente, on a observé, dans certains des groupes irradiés exposés aux plus fortes pressions de souffle, une augmentation accélérée du poids corporel au bout d'environ deux semaines.

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BOOK REVIEWS

CATHETER VERTEBRAL ANGIOGRAPHY. A clinical, angiographic and electro-encephalographic study of symptoms and signs (ophthalmic migraine, visual hallucinations and agnosias, disturbances of consciousness) accompanying vertebral angiography with various contrast media, and an evaluation of its indications and diagnostic value in intracranial morbid processes. By Tormod Hauge. 235 pages, 123 illustrations. Acta radiol. Suppl. 109, Stockholm 1954. Swed. Kr. 30: —.

Data of the various methods previously employed in vertebral angiography are briefly recorded.

The RADNER catheter method was employed throughout. A short description of the technical equipment and the procedure is included.

The material comprises 110 patients of ages ranging from 2 to 66 years, upon whom 133 catheterizations were performed.

The material has been sorted into 3 periods, each of which covers a stage in the development of technical and clinical experience; in the third period, catheterization of the vertebral artery was successful in 75 out of 76 patients. For each period, comments on certain conditions and anatomic anomalies liable to impede or prevent catheterization, are made.

A short historical review is given of the various contrast media and of complications met with in carotid angiography.

With increasing clinical experience and knowledge of the pharmacodynamic action of the contrast substances, a train of complications during and after vertebral angiography with various contrast media was registered. Symptoms recorded in connection with the diodrast group of media (Umbradil 35 per cent, Nycotrast 35 per cent) consisted of headache, nausea, vomiting, facial pain and earache, as well as signs of vertigo, pupillary changes, scintillations, hemiamblyopia, amblyopia, telescopic vision, monocular diplopia, peduncular hallucinations, Lilliput hallucinations and partial hallucinations. The opinion is advanced that the appearance of these symptoms and signs constitutes an experimental ophthalmic migraine.

Other visual disturbances, such as visual agnosias for objects, words, fingers and lateralization, Pick's visions, and cerebral metamorphosia, are also described. The cerebral localization of these signs is discussed.

As complications of greater gravity, the development of amnesia, dysartria, apathy and stupor passing into hypotonic unconsciousness, are listed. The correlation of the clinical phenomena to the angiographic and electroencephalographic findings, points towards an anatomic localization of this sign complex within that area of the brain stem, which depends upon its blood supply from the vertebral artery. Elderly patients and those exhibiting bulbar signs and/or intracranial hypertension are particularly liable to incur these serious complications. Even when Thorotrast was employed in such cases, a number of signs with attendant electroencephalographic changes, similar to those attached to the diodrast group, were recorded. Thorotrast is, however, shown to be more lenient than the diodrast group of media to a previously injured vascular wall, the latter

having led to complications of extreme gravity and to death in two of the cases. Thorotrast must therefore be the contrast medium of choice in elderly patients with manifest bulbar signs and/or intracranial hypertension.

Mention is made of the striking similarity of the symptomatology of the amnesia-dysarthria-stupor-hypotonia-coma complex to an experimental cerebral concussion. A hypothesis upon the cerebral localization and pathogenesis of the traumatic condition is consequently advanced.

The importance of the intracranial division of the vertebral circulation is emphasized. Supported by anatomic studies, an explanation is offered of fatal brain stem disturbances following ligature of one vertebral artery. The same vascular variant has also occasioned clinical speculations concerning the pathogenesis of certain Ménière-like attacks.

The importance of control injection in all the three arteries feeding the brain, irrespective of the seat of an arteriovenous aneurysm, is stressed as this malformation often receives blood from more than one main artery. The anastomotic connections between the carotid and cerebral arteries are established partly via the posterior cerebral artery, and partly via the posterior communicating artery. Similar anastomoses were demonstrated in cases of traumatic carotid-cavernous fistula, these anastomoses becoming pronounced after ligature of the common carotid artery.

The value of vertebral angiography in supratentorial expanding lesions is shown to be mainly supplementary, although occasionally it may be of decisive importance (central tumour).

Supported by anatomic studies and post-mortem angiographies it is shown that in infratentorial expanding lesions of low vascularity, displacement of the posterior inferior cerebellar artery, which traces the medial border of the tonsil, is of prime importance in the arteriographic diagnosis. As displacement of the tonsil, and with it the posterior inferior cerebellar artery, is more pronounced on the side on which the expanding process is situated, this observation is held to be of decisive importance in the choice of side for catheterization.

Various types of hemangioblastoma (Lindau tumour) are described together with observations on their blood supply and clinical manifestations.

Finally, a description of vertebral angiography performed in certain familial malformations of the brain is included.

An additional 140 vertebral catheterizations were later performed and are recorded under a separate heading (Addenda) together with comments on clinical phenomena observed in connection with vertebral angiography carried out with Angiopac.

Autoreview.

RÖNTGENANATOMISCHE GRUNDLAGEN DER LUNGENUNTERSUCHUNG. Von F. Kováts Jr.-Z. Zsebök. 288 pages, 315 illustrations. Akadémiai Kiadó, Budapest 1953. Ft. 180: —.

As the investigations described in the book are to a large extent based upon planigraphy, a chapter in the first part is devoted to the theory and practical significance of the method in the examination of the lung. This chapter contains nothing new excepting that the author points out the pros and cons of planigraphy. It is illustrated by a number of phantom investigations. By means of studies of comparisons of roentgen films (in the main, planigrams) with morbid specimens, the author then describes the relations of the organs of the thoracic cavity.

The bronchology, segmentation, and vascular system of the lungs, are dealt with in the chapters which follow. These form the chief part of the book and are of importance

in that they appear in the same work and follow one another so that one is enabled to obtain a conception of the roentgen anatomy of the lungs, regions of the hilum, and great vessels of the mediastinum, as a whole.

The author, furthermore, injected different coloured lead suspensions into the heart and lung vessels of cadaver. The organs of the thorax were then removed en bloc and planigraphed, following which, sections about 1 cm thick, were placed in both frontal and sagittal planes. These sections were then examined roentgenographically and the films obtained, as well as the planigrams, compared with the respective preparations.

The last chapter of the book consists of a roentgen-anatomic analysis of planigrams of the thorax.

The book contains only normal roentgen anatomy while pathologic conditions are not considered. Anomalies relatively often encountered are dealt with but sparingly. The illustrative material is generally excellent and there are explanatory sketches to a number of the roentgen films, which include details lost in the reproductions. It may perhaps be said as a final assessment that the book hardly passes the middle mark of the relatively large number of roentgenologic works which, by reason of the great advance in chest surgery, have appeared in the last few years.

Bengt S. Holmgren.

THE ROENTGEN ASPECTS OF THE PAPILLA AND AMPULLA OF VATER. By M. H. Poppel, H. G. Jacobson and R. W. Smith. 195 pages, 106 illustrations. Charles C. Thomas, Springfield 1953. $ 8.50.

In this study of the Vaterian segment, the authors first give a detailed anatomic description and an account of the embryonal development and factors favouring the origin of variants and anomalies. The authors' contribution is based on 100 post-mortem studies of both embryos and adults. A noteworthy result of the investigation is that the authors have shown that, while an ampulla is regularly present in young human embryos, it undergoes progressive involution during embryonal development.

An anatomic investigation of the papilla Vateri on post-mortem material is, however, probably of limited value and can hardly be used as a basis for evaluation of the conditions *in vivo*. This becomes obvious on comparison of roentgenographs of the preparations with those obtained at clinical examinations and included in the second part of the book, where the roentgen anatomy of the papilla is described on the basis of investigations carried out by means of a duodenal enema or ordinary routine barium meal. Routine examination by this method visualizes the papilla in about 50 per cent of the cases.

It is to be regretted that the roentgen aspects of the Vaterian region do not include an equally detailed account of the contrast filling via the ductus choledochus as of that via the duodenum. The authors refer mainly to peritoneoscopic cholangiography according to ROYER and to the modification by SLATTERY and SAYPOL, in which a sterile film holder is slipped into the space beneath the common bile duct and mobilized duodenum. However, as far as the evaluation of the anatomic conditions is concerned, these two methods do not offer any advantages over operative cholangiography according to MIRIZZI. With experience from a large material of operative cholangiography one cannot share the authors' opinion that the papillary region in cholangiography is usually masked by the superimposition of the duodenal contents. With such experience, the authors might also have emphasized more distinctly that, in adults, the ampulla Vateri merits its name in only exceptional cases.

The description the authors give of their own cases of malignancy of the Vaterian segment constitutes the most valuable chapter of the book. With knowledge of the value of cholangiography in the investigation of this region, too, it is, however, astonishing

that cholangiography was not performed in any of their 15 cases. Neither can their opinion be shared that the cholangiogram will show no changes as long as the Vaterian segment is not involved.

A fairly detailed bibliography is given, but no mention is made of the works of HJORTH and MILLBOURN. Nor does it include the name of FROSTBERG, whose 'inverted 3' sign is referred to on several occasions in the book.

The study gives a clear survey of the subject, the illustrations are informative, and the book is of value to radiologists and surgeons. However, as is apparent from the above considerations, the problem is not treated so exhaustively as one might have expected from the title.

Olof Norman.